JUL 5 1922

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ENGINEERING:

An Illustrated Weekly Journal.

EDITED BY WILLIAM H. MAW AND ALEX. RICHARDSON.

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ENGINES for Torpedo Boats, Yachts, Launches, BOILER FEED PUMPS.
See Advertisement, pages 25 and 29, last week.
PATENT WATER-TUBE BOILERS, AUTOMATIC FEED REGULATORS,
And Auxiliary Machinery as supplied to the Admiralty. 2179

John H. Wilson & Co., Ltd.,
Birkenhead.
See Illustrated Advertisement Page 100, Jan. 28, 1921.

Locomotive Shunting Cranes

Steam and Electric Cranes,
EXCAVATORS, CRANE-NAVVIES, GRABS, CONCRETE-MIXERS,
SHIPS' WINDLASSES, WINCHES, and DECK MACHINERY. 837
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Sole Makers: June 16.
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Cochran MULTITUBULAR AND CROSS-TUBE TYPES.
Boilers.
See page 17, June 16. 9047

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TRANSPORTER CO., LTD.,
CONTRACTING ENGINEERS.

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all Classes of HANDLING MACHINERY.

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Two and Four stroke, 350, 1000, 1200 H.P., excellent condition. Dynamos for above 250 or 500 volts, D.C. Immediate delivery and low price.
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Any class of tools. H. S. Chasers for adjustable die heads. Case hardening, colouring, etc. We can case harden Cast Iron for gauges, press tools, etc. Write us for particulars. Reliable Work! Right Prices! Delivery to promise!
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Sole Licensees in Great Britain for the manufacture of "Armco" Best and Corrosion Resisting Iron Tubes. 9246
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See Advertisement page 73.

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ENGINEERS, IRLAM, MANCHESTER.
FEED WATER HEATERS, CALORIFIERS, EVAPORATORS, } ROW'S PATENTS.
CONDENSERS, AIR HEATERS,
Merrill's Patent TWIN STRAINERS for Pump Suctions.
SYPHONIA STEAM TRAPS, REDUCING VALVES
High-class GUNMETAL STEAM FITTINGS.
WATER SOFTENING and FILTERING. 8723

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IRON AND STEEL
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MANCHESTER WAREHOUSE—34, DEANSGATE.
CARDIFF WAREHOUSE—132, BUTE ST.
BIRMINGHAM WAREHOUSE—MILK STREET, SHERLOCOTE STREET.
See Advertisement, page 26. 9252

Economy!
HIGH BOILER EFFICIENCIES
ARE OBTAINED BY INSTALLING
Todd Oil Burners
FUEL OIL BURNING SYSTEMS,
HEATERS, STRAINERS.
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Builders of Steam and Motor Ships, Repairers, Electric Drive Installations.
Twenty-one Floating Docks, Two Graving Docks, Twelve Shipways.
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Great saving of labour. No noise. No dust. No dirt. Ashes discharged 20 ft. clear of vessel.—Apply, F. J. TREWENT & PROCTOR, LTD., Naval Architects and Surveyors, 43, Billiter Bldgs., Billiter St., London, E.C. Od 4825

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London Office: 101, LEADENHALL ST., E.C. 3.
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Makers of
Evaporating and Distilling Plants.
Refrigerating and Ice-Making Machinery.
Feed Water Heaters.
Evaporators.
Fresh Water Distillers.
Main Feed Pumps.
Combined Circulating and Air Pumps.
Auxiliary Surface Condensers.
&c. &c. 9804

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T.N. 4515 Museum. 9675

Electric Cranes.
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Transporters.
Lifts.
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PRESSED STEEL WORK OF ALL KINDS.
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Yarrow Patent
Water-Tube Boilers. 9564
Messrs. YARROW & CO. UNDERTAKE the PRESSING and MACHINING of the various parts of Yarrow Boilers, such as the Steam Drums, Water Pockets, and Superheaters for British and Foreign Firms not having the necessary facilities.
YARROW & CO. (1922), LTD., SCOTSTOUN, GLASGOW.

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GENERAL CONSTRUCTIONAL ENGINEERS. 1316
Boilers, Tanks & Mooring Buoys
STILLS, PETROL TANKS, AIR RECEIVERS, STEEL CHIMNEYS, RIVETTED STEAM and VENTILATING PIPES, HOPPERS, SPECIAL WORK, REPAIRS OF ALL KINDS.

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THE GLASGOW ROLLING STOCK AND PLANT WORKS, MOTHERWELL. Od 3383

Head, Wrightson & Co.,
LIMITED.
See Advertisement page 46, June 16. 240

A. P. Thurston, D.Sc.
Engineering. Expert advice on Patents, Inventions, Models and Designs.—79, Southampton Buildings, W.C. 2. Holborn 2845. 9661

Crane and Sling Chains up to
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GOLD MEDAL-INVENTIONS EXHIBITION-AWARDED.
Duckham's Patent Suspended
WEIGHING MACHINES.—EAST FERRY ROAD ENGINEERING WORKS COMPANY, LTD. LONDON, E.—Hydraulic Cranes, Grain Elevators, &c. See Illus. Advt. last week, page 15. 9764

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Centrifugals.
Pott, Cassels & Williamson,
MOTHERWELL, SCOTLAND. 9737
See half-page Advertisement page 66, June 9.

See Advt. Page 84 June 16. **Steam Hammers**
Power Hammers
Steam and Friction
Drop Stamps.
B. & S. Massey, Ltd., 9911 MANCHESTER.

The Manchester Steam Users' ASSOCIATION.

For the prevention of Steam Boiler Explosions and for the attainment of Economy in the Application of Steam. 9, MOUNT STREET, MANCHESTER.
Chief Engineer: C. E. STROMEYER, M.I.C.E.
Founded 1854 by Sir WILLIAM FAIRBAIRN.
Certificates of Safety issued under the Factory and Workshops Act, 1901. Compensation for Damages and Liabilities paid in case of Explosions. Engines and Boilers inspected during construction. 598

Finsbury Technical College, LEONARD STREET, CITY ROAD, E.C.2.

Dean for the Session, 1921-22.
PROFESSOR W. H. BOOLES, D.Sc., F.R.S.

The College provides practical scientific training for students who desire to become Civil, Mechanical or Electrical Engineers, or Chemists.
Candidates are required to pass an Entrance Examination in Mathematics and English, but the Matriculation Certificate of any British University, and certain other qualifications, are accepted in lieu of it. The next ENTRANCE EXAMINATION will be held on TUESDAY, SEPTEMBER 19th. Applications for admission should be forwarded to the College on forms to be obtained from the REGISTRAR. The Programme of the College is under revision and will be issued shortly. U 480

1922 B. No. 2693.
IN THE HIGH COURT OF JUSTICE.
CHANCERY DIVISION.
MR. JUSTICE SARGANT.
In the Matter of Letters Patent No. 116 of the year 1907 granted to Summers Brown of 40 Whitecross Street E.C.
and
In the Matter of the Patents and Designs Acts 1907 and 1919.

Notice is Hereby Given that

Summers Brown of 38 Bedford Street Strand in the County of London and Roneo Limited whose Registered Office is situate at 5-11 Holborn in the City of London have by Originating Summons dated the 22nd day of May 1922 applied that the term of the above mentioned Letters Patent may be extended, and notice is hereby given that on Tuesday the 25th day of July 1922 application will be made to the Court that a day may be fixed before which the said Summons shall not be in the paper for hearing. And notice is hereby given that any persons desirous of being heard in opposition to the said Originating Summons must at least seven days before the said 25th day of July 1922 lodge notice of such opposition in the Chambers of Mr. Justice Sargant Room 187 Royal Courts of Justice Strand London and serve a copy thereof upon the undersigned F. P. Woodcock the Applicants' Solicitor. And notice is hereby given that the address of the undersigned F. P. Woodcock is the address for service on the applicants Summers Brown and Roneo Limited of any documents requiring service upon them in accordance with Order 53a Rule 3a of the Supreme Court.
Dated this 15th day of June, 1922. U 511
F. P. WOODCOCK,
5, Holborn, E.C. 1.
Applicants' Solicitor.

Correspondence Courses for

Inst. Civil Engrs., Inst. Mech. E., London Univ. (Matric., Inter., B.Sc.), and ALL ENGINEERING EXAMINATIONS personally conducted by MR. TREVOR W. PHILLIPS, B.Sc. (Honours), Assoc. M.Inst.C.E., M.R.S.I., F.R.S.A., &c. Also Day Tuition in Office. Excellent results at all Exams. Courses may commence at any time, and all Students receive individual tuition.—For full particulars apply to S/11, TRAFFORD CHAMBERS, 58, SOUTH JOHN STREET, LIVERPOOL. 575

Inst. C.E., I. Mech. E., B.Sc.,

and all Engineering Examinations.—Mr. G. P. KNOWLES, B.Sc., M.I.E., A.M.Inst.C.E., F.S.I., M.R.San.I., PREPARES CANDIDATES personally or by correspondence. Thousands of successes during the last sixteen years. Courses may commence at any time.—39, Victoria St., Westminster, S.W. Tel. 4780 Victoria. 745

Inst. C.E. Exams.—Successes

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Powering of Vessels.—A

Practical Course of Instruction by Correspondence.—Address, for particulars and terms, 748, Offices of ENGINEERING.

TENDERS.

THE METROPOLITAN ASYLUMS BOARD invite

Tenders for the Work of

DREDGING at South Wharf, Rotherhithe, London, S.E. 16, in accordance with specification by Mr. THOMAS COOPER, M.I.C.E., Engineer-in-Chief to the Board.
Specification, Conditions of Contract and Form of Tender may be obtained at the Office of the Board, Embankment, E.C. 4.
Tenders, addressed as noted on the form, must be delivered at the Office of the Board not later than Ten a.m. on Thursday, 6th July, 1922.
G. A. POWELL,
Deputy Clerk to the Board.
19th June, 1922. U 530

BOMBAY, BARODA AND CENTRAL INDIA RAILWAY COMPANY.

The Directors are prepared to receive up to Noon on Friday, 14th July,

Tenders for the Supply of

METALLIC FILAMENT LAMPS.
Tenders must be made on forms, copies of which, with Specification, can be obtained at these offices on payment of 10s. each (which will not be returned).
The Directors do not bind themselves to accept the lowest or any Tender.
S. C. R. YOUNG,
Secretary.
Offices:—
21, Petty France,
Westminster, S.W. 1.
21st June, 1922. U 534

EAST INDIAN RAILWAY.

The Directors are prepared to receive up to Eleven o'clock a.m. on Wednesday, the 5th July proximo,

Tenders for the Supply of

1. STEEL MATERIAL.
2. WROUGHT IRON.
3. GALVANISED STEEL WORK.

Copies of the specification can be obtained at the Company's Offices on payment of £1 1s. This fee will not be returned.
G. E. LILLIE,
Secretary.
70/6, King William Street,
London, E.C. 4.
20th June, 1922. U 546

SCUNTHORPE AND FRODINGHAM URBAN DISTRICT COUNCIL.
WATERWORKS EXTENSION.
FOR SALE, PUMPS, &c.
The above Council have

For Sale, at their Waterworks,

the following PLANT, practically new, viz:—
One set 10½ in. by 24 in. Tangyes TREBLE DEEP WELL PUMPS, 35,000 gallons per hour output against a head of 200 feet, with suction, strainer, foot-valve and delivery complete. Fitted with overhead gear arranged for direct drive by 60 H.P., A.C., 3 phase, 50 period, 2200 volt motor with switch gear complete. A complete installation.
Fullest particulars and makers' detailed specifications may be obtained and plant inspected on application to undersigned, to whom Offers are to be sent.
ALEXANDER M. COBBAN,
Engineer.
Council Offices,
Market Hill, Scunthorpe,
June 16th, 1922. U 518

THE HIGH COMMISSIONER FOR INDIA is prepared to receive

Tenders for the Supply

of:—
1. STEEL SCREW SPIKES for rails.
2. MILD STEEL HOOP.
3. CABLE, underwater, unarmoured, single wire, brass taped, G.P.
4. CABLE, five wire, V.I.R. insulated and Lead sheathed.
5. BRAIDED WIRE for crossings over power circuits.
6. STEEL STRIP for chargers.

Forms of Tender may be obtained from the Director-General, India Store Department, Belvedere Road, Lambeth, S.E. 1, and Tenders are to be delivered at that Office not later than Two o'clock p.m., on Friday the 7th July, 1922, for Nos. 1 and 2, on Friday the 14th July, 1922, for Nos. 3 to 5, and on Friday the 21st July, 1922, for No. 6.
T. RYAN,
Director-General. U 552

COUNTY BOROUGH OF BRIGHTON.
TO CONTRACTORS AND OTHERS.
NOTICE IS HEREBY GIVEN that the Council of the said County Borough will receive

Tenders from such Persons

as may be willing to enter into a Contract for CONSTRUCTING and COMPLETING HEADINGS and BORE-HOLES, and other Works in connection with the Falmer Pumping Station, Falmer, Sussex.
The Specification and form of Tender may be obtained on application at my Office at the Town Hall, Brighton.
Sealed Tenders, addressed to me and endorsed "Tender for Construction of Headings, &c.," must be left at my office at the Town Hall before Ten o'clock in the forenoon, on Tuesday, the Fourth day of July, 1922.
The Council do not bind themselves to accept the lowest or any Tender.
Persons Tendering must do so at their own expense.
HUGO TALBOT,
Town Clerk.
Town Hall, Brighton.
15th June, 1922. U 509

CORPORATION OF DUBLIN.
TO MANUFACTURERS OF SEWAGE PUMPS AND ELECTRIC MOTORS.
The Corporation of Dublin are prepared to receive

Tenders for the Supply and

ERECTION of TWO SETS of ELECTRICALLY-DRIVEN SEWAGE PUMPS, each capable of dealing with 18,000,000 gallons per diem, together with Auxiliary Works, for their Ringsend Pumping Station, in the City of Dublin.
The Specification may be inspected at the Office of the City Engineer, Mr. MICHAEL J. BUCKLEY, 26, Castle Street, Dublin, and at the Office of the Consulting Engineer, Mr. JOHN S. ALFORD, 11, Victoria Street, Westminster, London, S.W. 1, between the hours of Eleven a.m. and Four p.m., Saturdays excepted, from 26th June. A limited number of copies of the Specification, Form of Tender, Drawing and blank Diagram for guaranteed pump performance, may be obtained at the aforesaid offices on payment of Five Guineas (crossed cheque only). The deposit will be refunded on the return of the whole of the documents and the receipt of a *bona fide* Tender.
Tenders, sealed and endorsed on the envelope "Tender for Pumps C1 and D1," are to be addressed to the Chairman of the Streets Committee, Municipal Buildings, Dublin, and must be delivered before noon on Tuesday, the first day of August, 1922.
With each Tender must be submitted names of two or more sureties, an Insurance Company or a Bank who will be prepared to execute a joint and several bond for the due performance of the contract in a sum equal to the amount of the tender.
The Specification contains stipulations governing the labour conditions of the contract, and which include the employment of Trade Union labour, the payment of standard rates for and the observance of standard hours of labour, the employment of local labour, and requiring the use of Irish materials and Irish workmanship, except in cases where they cannot be obtained.
The Corporation do not bind themselves to accept the lowest or any Tender.
JOHN J. MURPHY,
Town Clerk's Office, Town Clerk, Dublin.
City Hall, Dublin.
19th June, 1922. U 536

THE BURMA RAILWAYS COMPANY, LTD.
The Board of Directors of the Burma Railways Co., Ltd., are prepared to receive

Tenders for the Supply of

(a) 83,884 STEEL FISHBOLTS, with NUTS and WASHERS for 60 lbs. Steel Rails.
(b) 637,200 DOG SPIKES, W.I., for 60 lbs. Steel Rails.

For each copy of the Specifications (a) and (b) a fee of 10s. will be charged, which fees are not returnable. Tenders enclosed in sealed envelopes endorsed "Tender for Steel Fishbolts" or "Tender for Dog Spikes" as the case may be, must be delivered at the Company's Offices not later than Twelve noon on Monday, 3rd July, 1922.
The Directors do not bind themselves to accept any or the lowest tender, and reserve the right to divide the order.
By order of the Board,
F. C. FRANKS,
Secretary.
199, Gresham House,
Old Broad Street,
London, E.C. 2.
21st June, 1922. U 555

APPOINTMENTS OPEN.

UNIVERSITY OF BIRMINGHAM.
ASSISTANT LECTURER IN CIVIL ENGINEERING. GRADE II.

Applications are Invited for

the POST of ASSISTANT LECTURER in the Civil Engineering Department. Commencing stipend, £400 per annum.
A good University Degree and Practical Experience of Constructional Engineering are essential.
Applications, with testimonials and references should be forwarded to the undersigned not later than July 4th.
Further particulars may be obtained from—
GEO. H. MORLEY, Secretary. U 475

Wanted, Manager-Secretary

for Shipbreaking Company. Must have practical and commercial experience. Preference will be given to one with knowledge of shipbreaking. State age, experience and salary required.—Address, U 537, Offices of ENGINEERING.

Works Manager for Small

Engineering Works. Knowledge and experience of Welding and Steam Fitting Manufacture essential. State experience, age, and salary required. Copies only of testimonials.—Address, U 525, Offices of ENGINEERING.

Engineer Representative,

London area, WANTED by Firm manufacturing a high-class engineering speciality. Applicants must have sound and thorough engineering experience. State age, experience, salary required.—Address, U 514, Offices of ENGINEERING.

SINGAPORE, STRAITS SETTLEMENTS.
WATER DEPARTMENT.
ASSISTANT SUPERINTENDENT OF WATER MAINS AND SERVICES.
The Municipal Commissioners of Singapore require an

Assistant Superintendent of

Water Mains and Services, age about 27 to 33 (preferably unmarried), on a three years' agreement, with possible extension. Applicants must have had a good education, be well trained and have had special practical experience in the laying of Water Mains and outside Water Fittings, as well as internal plumbing. They must be "Registered Plumbers," with experience in the work of a mains and services department under a water authority in the United Kingdom, and must be accustomed to carrying out the model by-laws and regulations. They should be accustomed to controlling men, and experience in a workshop and in training men will be an advantage, as the successful candidate would be required to instruct the native subordinate staff in the practice and requirements of modern internal plumbing for public and private buildings. He would also be required to supervise such work in accordance with standard regulations, whether executed by outside contractors or by municipal workmen. A bonus of $30 will be given on the selected candidate's passing successfully an examination in colloquial Malay within twelve months of his arrival in Singapore. Salary $4560 for the first, $5040 for the second, and $5520 for the third year, paid monthly, in dollars, the currency of the Colony, the value of the dollar being two shillings and fourpence sterling. In addition there is a Temporary Allowance of 15 per cent., which may be reduced or abolished at any time. If re-engaged, the candidate, in his fourth year, would probably be placed in class 5 of the salary scheme, at a commencing salary of $6000 per annum (£709), rising by annual increments of $480 to $7440 (£868) per annum, with any temporary allowance that might then be in force. The pay of the appointment for the first year at the above rate would be about £611. Such local transport allowance as may from time to time be sanctioned by the Commissioners will be paid. Free second-class passage will be provided, with half-pay during the voyage out. The selected candidate must pass a medical examination. — Applications, stating whether married or single, age, and place of birth, and giving details of education, apprenticeship, training, and experience generally, with war service, and referring to the above requirements in detail, accompanied by copies (only) of testimonials, and also personal references, are to be lodged with Messrs. C. C. LINDSAY & PRIROE, M.M.Inst.C.E., 180, Hope Street, Glasgow, Agents to the Commissioners (who will give further particulars if requested), not later than Thursday, 6th July, 1922. U 547

The Services of a Competent

GENTLEMAN are REQUIRED for the post of CHIEF ENGINEER at a large iron and steel works near the East Coast. In making the selection preference will be given to men who have had thoroughly practical experience in the economic running of sheet bar mills. Applicants should also have had experience in modern coke oven, blast furnace and steel furnace design and maintenance, as well as all auxiliary plant appertaining thereto. Only thoroughly live men need apply. Suitable house available. Applications, giving age, experience and salary required, together with recent references.—Address, U 539, Offices of ENGINEERING.

Machine and Small Tool

SALESMAN REQUIRED, with genuine connection, by London Merchants.—Address, U 519, Offices of ENGINEERING.

BOMBAY MUNICIPALITY.

Required, One Mechanical

ENGINEER AND THREE ASSISTANT MECHANICAL ENGINEERS to supervise the manufacture of 72 in., 60 in. and 57 in. diameter Steel Pipes in the Workshops near Bombay, and the assembling and laying of the same along 60 miles of pipe track outside Bombay.
All Applicants should be between 35 and 45 years of age.
The Mechanical Engineer should have had a good technical education and considerable practical experience in structural steel work, boiler making, &c., and have held a responsible position as Works' Manager, Shift Engineer or similar post, in a shipyard, railway or large commercial firm.
Assistant Engineers should have had similar experience in a less responsible position such as Works' Foreman or Foreman Boiler Maker, &c.
The salary for the Mechanical Engineer is Rs. 1500 per month without quarters. The salary for the Assistant Engineer is Rs. 800 per month with tent or quarters and simple furniture; no accommodation is provided for wife or family.
All the appointments are temporary, but are not expected to terminate within three years.
The salary will commence from date of joining appointment in Bombay, and single first-class rail fare to Bombay will be paid to applicants selected from India.
Single first-class P. & O. passage from London to Bombay for the Mechanical Engineer, and second-class P. & O. passages for the Assistant Engineers will be provided if applicants are selected from the United Kingdom, with half salary on voyage.
Similar return passages and half salary on voyage being allowed on satisfactory completion of their duties.
All appointments are subject to three months' notice on either side.
All selected candidates will be required to furnish a Medical Certificate of sound health and constitution prior to engagement. They will be entitled to leave according to the Municipal Leave Rules.
Selected candidates will be required to enter on their duties in Bombay early in December, 1922.
Applications, stating age, qualifications and experience, together with copies of testimonials, should be addressed to the undersigned, and will be received up to 31st August, 1922.
H. J. TRIVESS SMITH, M.I.C.E.,
Hydraulic Engineer,
c/o Messrs. HENRY S. KING & Co.,
9, Pall Mall, London, S.W. 1. U 509

Assistant Engineer

REQUIRED by the Government of NIGERIA for the Lagos Harbour Works, for two tours of 12 to 18 months each, with possible extension. Salary £600, rising to £720 a year by annual increments of £30 and thence to £920 a year by annual increments of £40. An outfit allowance of £60 paid on first appointment. Free single quarters and passages. Liberal leave in England on full salary. Candidates, age between 23 and 35, must be duly qualified civil engineers and must have had a wide experience (including dress diving) on an engineer's or contractor's staff in the actual construction of Harbours and Dock Works, both by contract and departmentally.
Apply, at once, by letter, giving age and brief details of experience, to THE CROWN AGENTS FOR THE COLONIES, 4, Millbank, Westminster, S.W. 1, quoting M/11500. U 550

Wanted, an Electrical

ENGINEER for large iron and steel works near the East Coast. Applicants must be thoroughly experienced in the maintenance and upkeep of all plant and appurtenances connected with generating and transmitting power for all purposes, and be conversant with the most economic and up-to-date methods of running the whole of the electrical equipment. Suitable house available. Applications, giving age, experience and salary required, together with recent references.—Address, U 538, Offices of ENGINEERING.

Wanted, at Once, First-class

DRAUGHTSMAN thoroughly experienced in the design of all sizes of Electric Cranes. Preference given to one who has had considerable practice in estimating. State age, experience and salary required.—Address, U 549, Offices of ENGINEERING.

Wanted, Chief Draughtsman

by Firm of General Engineers in the Midlands, accustomed to control of Office routine and experienced in Hydraulic and General Engineering.—Address, stating age, experience and salary required, U 548, Offices of ENGINEERING.

Wanted, Fully Qualified

AUTOMOBILE DRAUGHTSMAN. Preference will be given to applications from men who have specialized in Commercial Vehicle Design.—State age, experience and salary expected to Box No. C.M. 340, c/o DAWSON'S, 121, Cannon Street, E.C. 4. U 471

Draughtsman. — Wanted, on

N.E. Coast, in large Constructional Works, FIRST-CLASS DRAUGHTSMAN, with latest modern blast furnace experience. No application except from men with this experience will be considered. Good wages to right man.—Address, U 498, Offices of ENGINEERING.

Leading Draughtsman

REQUIRED by Aerial Ropeway Specialists. Must be thoroughly experienced. Good prospects for suitable man. State full particulars of experience, salary required, &c.—Address, U 526, Offices of ENGINEERING.

Wanted, Designing Draughtsman,

capable of developing new line of Centrifugal Pumps. Must be technically trained and capable of assuming full charge of work. Location, Lancashire. State age, education, practical experience and salary expected.—Address, U 534, Offices of ENGINEERING.

Chief Draughtsman Required,

fully conversant with modern Lift practice and with knowledge of Crane work.—Apply, stating age, experience and salary required to PICKERINGS LIMITED, Stockton-on-Tees. U 533

First-Class Draughtsman

WANTED. Must have had wide experience and shop training. Some experience of aeroplane work desired.—Address, U 527, Offices of ENGINEERING.

THE CONSERVATOIRE NATIONAL DES ARTS ET MÉTIERS.

THE imposing series of buildings which are now occupied by the Conservatoire National des Arts et Métiers in Paris, and of which a plan is given in Fig. 1 subjoined, were formerly, and for a period of over seven centuries, a monastery belonging to the Order of Benedictines. The monastery was founded in 1060, and was known as the Priory of St. Martin-in-the-Fields. It was abolished, and the site and buildings were appropriated by the Nation in 1790, at the time of the French Revolution. In the early period of its existence as a priory, and for many years, it was outside the French metropolis. The area covered was about 15 acres. It contained, as far back as the sixteenth century, a number of admirable buildings, and its surrounding walls, shown in old engravings, were evidently designed and built by military experts of the time, for they afforded the priory most adequate protection against incursions. A part of these old walls, with a portion of the watchman's path and a watch tower, can still be seen, and are illustrated in Fig. 2 on page 772. The cloisters, in particular, formed a most remarkable building; they were connected to a church, an admirable one in every respect, although the apsis and the nave were of two different orders of architecture. They were also connected to a refectory, which is said to have been designed by Pierre de Montereau, the architect of the Sainte-Chapelle. These buildings still exist, the church containing collections of machinery and models, whilst the refectory has been transformed into a library. The refectory is illustrated in Fig. 3 on page 772 and the church in Fig. 4 on Plate XLII.

The Conservatoire des Arts et Métiers was instituted by a law dated October 10, 1794. Since April 2, 1799, the various existing buildings have been organised for their new purpose, and others have been added at different times. The ground floor of the Conservatoire, as it now stands, is shown in the plan, Fig. 1, to which we have already referred. Some of the older parts of the buildings are shown in Figs. 2 to 4, already mentioned, while the main elevation of the Conservatoire to the Rue St. Martin is illustrated in Fig. 5 on Plate XLII. The main central gallery devoted to models of locomotives and machinery is shown in Fig. 6 and the gallery illustrating the many advances in clockwork design in Fig. 7, both on Plate XLII.

The law of October 10, 1794, established that "there shall be constituted in Paris, under the name of Conservatoire des Arts et Métiers, a depôt of machines, models, tools, drawings, descriptions and books covering all classes of arts and crafts, the establishment, further, to give instruction concerning the construction and the use of machinery destined to promote arts and crafts; the said establishment to be in charge of three demonstrators and one draughtsman." A report annexed to the law in question, stated that "the establishment shall contain representative types of all pieces of machinery which work both efficiently and rapidly, and are of an improved type, the criterion followed in their selection to be based not simply upon any given system, but also upon tests carried out in actual practice, the said tests to afford a guarantee of the useful purpose served by the machinery in question." The industrial museum, thus created, took over the collection which at the time existed at the former Académie des Sciences, that of the celebrated inventor and engineer, Vaucanson, and the collection of the Hôtel d'Aiguillon, containing articles of furniture, and other exhibits which had belonged to the Crown. These collections of machinery, models, instruments, were rapidly increased by further acquisitions, and are regularly being added to at the present day.

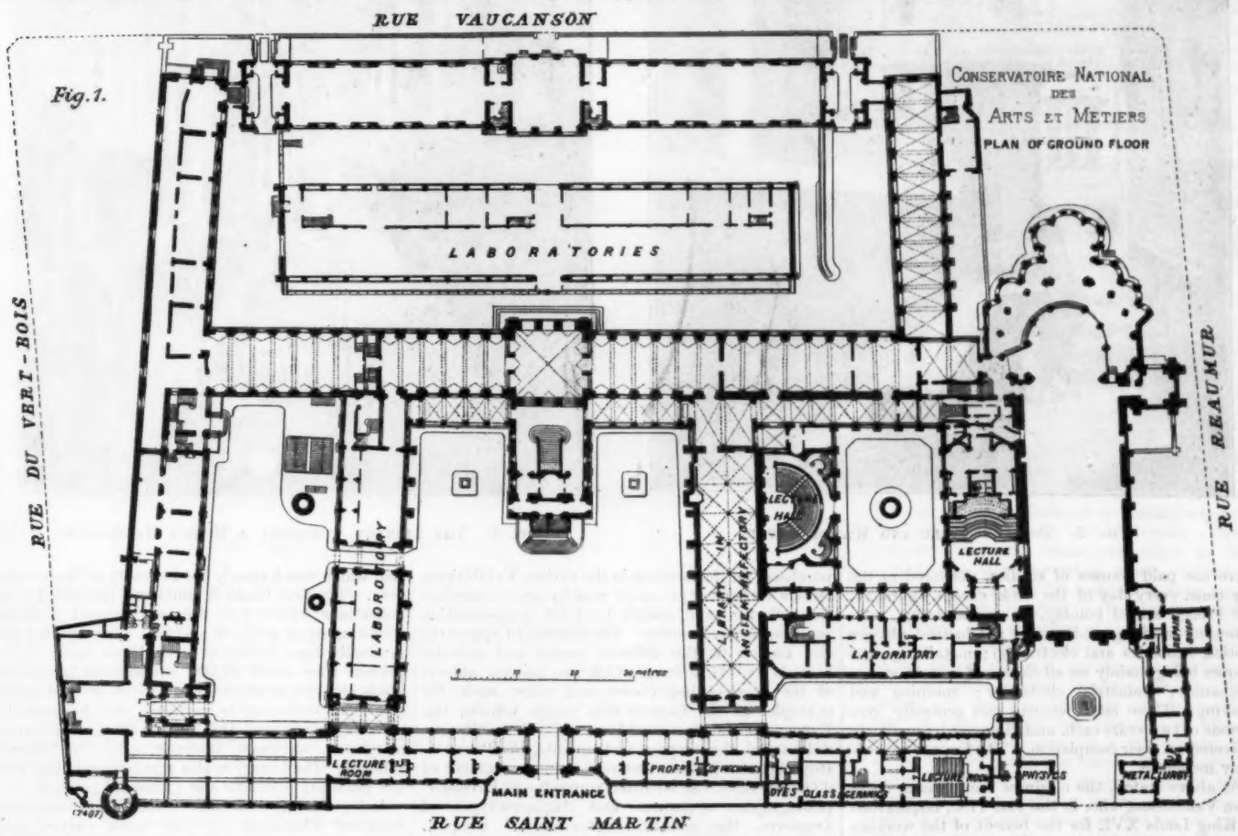
Following upon the law of October 10, 1794, the ancient monastery of St. Martin-in-the-Fields was appropriated to serve as the Conservatoire, by virtue of a law dated June 10, 1798; the installation therein of the various collections then existing commenced on April 2, 1799, the date above named.

At first, and down to the year 1819, the new Institution was to afford visible evidence of the value of machinery, by means of models, concerning which explanations and demonstrations were given periodically. In 1819, a step forward was taken by establishing series of lectures in science applied to arts and industries, an innovation which formed the subject of a law passed on November 26, 1819, the preamble of this stating that, "whilst the Conservatoire des Arts et Métiers has rendered important service since its formation, the aim had in view can only be fully attained by the addition of a high-school to impart knowledge in connection with commercial and industrial subjects." Free public lectures were then instituted, there being, at first, three courses only, on mechanics, applied chemistry and industrial economics. Since then, over twenty other courses have gradually been added, and moreover, public conferences are now held on Sunday, during the winter months, on subjects of current scientific interest. A series of laws passed between the years 1900 and 1907 have further organised the working of the establishment, extended its scope and regulated its financial status. Although the Conservatoire is a national institution, it has a certain independence, and can, for example, receive financial aid and inherit legacies from companies and persons in private life. It is not only a museum combined with a department for the teaching of technics, but also a laboratory for research and for chemical analyses and physical tests, and an institution for demonstrating the great value of "safety-first" appliances. It is administered by a Board formed of eminent scientists, business men and professors.

Such is a brief history of the Paris Conservatoire des Arts et Métiers, which is now situated practically in the centre of the town, 292, Rue St. Martin, a street which gives on the Boulevard of the same name. We may conveniently divide our further description of the establishment as it exists at the present day under the five following headings: Technical Education, Museum, Library, Laboratory, and Safety-First Department.

There are in the buildings four separate lecture-halls, in which free lectures are delivered regularly every week, in the evenings, on twenty-four different subjects, such as geometry, mechanics, physics, electricity, metallurgy, spinning and weaving, civil engineering, agriculture, political economy, &c.; all the lectures being given by well-known French professors. Besides these free evening lectures,

Fig. 1.



THE CONSERVATOIRE NATIONAL DES ARTS ET MÉTIERS, PARIS.

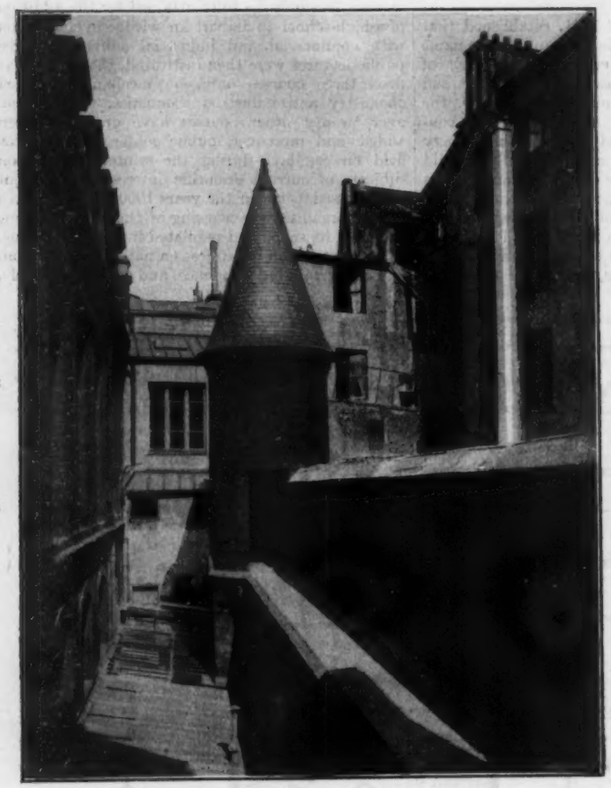


FIG. 2. THE OLD WALL AND WATCH TOWER.

FIG. 3. THE LIBRARY, FORMERLY A MONK'S REFECTORY.

there are paid courses of studies, delivered in the day-time, every day of the week, except Thursday, the French school holiday, on engine design, construction, working and testing; industrial physics (optics, acoustics and electricity); metallurgy, the courses being mainly on all classes of metal testing; mechanics; industrial electricity; spinning and weaving. These latter courses run generally over periods of two years each, and diplomas by merit are delivered on their completion. The fees are exceedingly moderate.

As above stated, the origin of the museum dates from Vaucanson, who, in the year 1782, bequeathed to King Louis XVI, for the benefit of the working classes, his collection of machines and tools. This collection contains among other objects of great historical interest, the silk weaving loom which inspired Jacquard in the design of his own machine and formed as it were the commencement of the installations which have so greatly contributed to the wealth of the Lyons districts. A large number of articles were added in 1807. Ferdinand Berthoud then bequeathed to the museum his admirable collection of time-pieces; the State purchased in the same year and for the same purpose the collection of physical instruments which belonged to the physicist Charles, the most complete of its day and a large portion of which proceeded from the collection of Abbé Nollet. The machines, tools and instruments of Rochon were purchased from 1806 to 1812. The first general catalogue of the museum was considered in 1816 and was published in 1818. Funds for the formation of the museum were first constituted by the Government of the First Republic; under the Consulate and the First Empire there were added contributions made by the Académie des Sciences and various Ministries; then came aid granted by the Paris Chamber of Commerce, the Société d'Encouragement pour l'Industrie Nationale, and contributions made by manufacturers, inventors and scientists. The State has also made purchases for the museum in the various Exhibitions. Orders are further given out year by year to increase the collection and models used for demonstration purposes in the lectures. The number of apparatus and models in the different rooms and galleries exceeds 15,000, among which are historic objects of the greatest importance and value, such, for example, as the Cugnot first steam vehicle, the Vaucanson and Jacquard looms, the Foucault pendulum and the ampere instruments, the Pierre-le-Roy chronometer, the first registering instrument of d'Ons-en-Bray, the scientific apparatus of Lavoisier, photographic apparatus and daguerreotypes of Daguerre, the scientific collection of Bréquet, original photophones of Graham Bell, besides innumerable specimens covering practically every art, trade and industry. An important collection of apparatus illustrating the history and the evolution of telegraphy and telephony was opened in December, 1921.

We illustrate in Fig. 8, on page 773, the Cugnot steam-driven, road car, in the museum. This was built in 1770. When carrying four persons, on a flat road, a similar car to the one illustrated had a speed of 1,800 toises to 2,000 toises (2 miles to 2·5 miles) per hour. But the capacity of the boiler not being proportionate to the cylinder capacity, the vehicle could not run for a longer time than from 12 minutes to 15 minutes, when it had to stand still for an equal length of time when a further quantity of steam was generated in the boiler. Thereupon Cugnot received an order for a better proportional vehicle, one which when loaded with 8 milliers to 10 milliers (4 tons to 5 tons) would run continuously at a speed of 2 m.p.h. This latter car is the one at the museum, illustrated in Fig. 8. It does not appear to have been ever tested on the road. Fig. 9 illustrates a model of the first locomotive having a fire-tube boiler built in 1827 by Marc Seguin, for the St. Etienne-Lyons Railway.

The library, as already stated, is located in the hall which was formerly the refectory of the monastery. The first books it contained proceeded from collections which had become national property following upon political events; their number has gradually been increased since, there being at the present time about 57,000 publications of various kinds covering sciences, arts, agriculture and industry. The collection is increased year by year, by gifts and purchases. It is open to all manufacturers, merchants, workmen, students in all the different colleges. The library is also regularly supplied with the principal scientific and industrial journals.

Independently of the research laboratories, rendered illustrious by the work carried out therein by Becquerel, Boussingault, General Morin, Péligot, Schloesing, and others, the testing laboratory was instituted by virtue of a decree dated May 19, 1900, and its working formed the subject of a further decree dated July 9, 1901, following an agreement passed in June of the latter year, between the Ministry of Commerce, Industry Posts and Telegraphs, the Conservatoire des Arts, et Métiers and the Paris Chamber of Commerce. The object of the laboratory is to enable the State Departments, manufacturers, merchants and also private persons to obtain expert opinion by means of mechanical tests, physical tests, chemical analyses of any product in which they are interested, and to arrange for the testing of any machinery. The laboratory is divided into five sections, each one complete in itself. Section I deals with general physics tests (electrical instruments excepted), covering the verification of pressure gauges, thermometers speed and other indicators, telescopes, prisms, photographic apparatus, weights and scales, measuring apparatus, screw threads, &c. Section II is set apart for mechanical tests and the micrographic inspection of metals; iron, cast-iron, steel, special steels, alloys, pipes, tubes, files, cables, &c., and tests of timber, ropes, tissues, rubber. Section III deals with mechanical tests on all classes of

CONSERVATOIRE NATIONAL DES ARTS ET MÉTIERS.

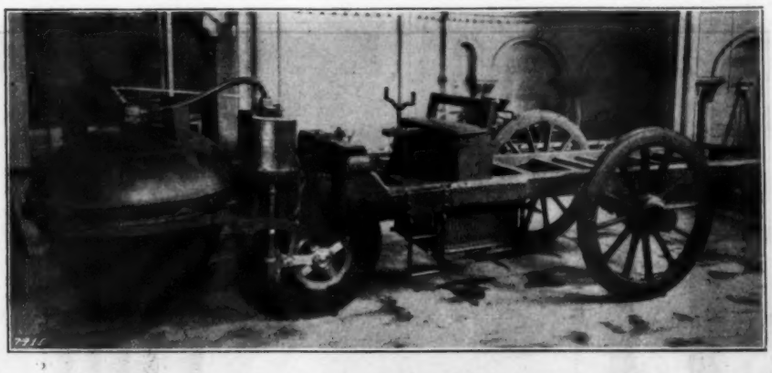


FIG. 8. THE CUGNOT STEAM-DRIVEN ROAD CAR BUILT IN 1770.

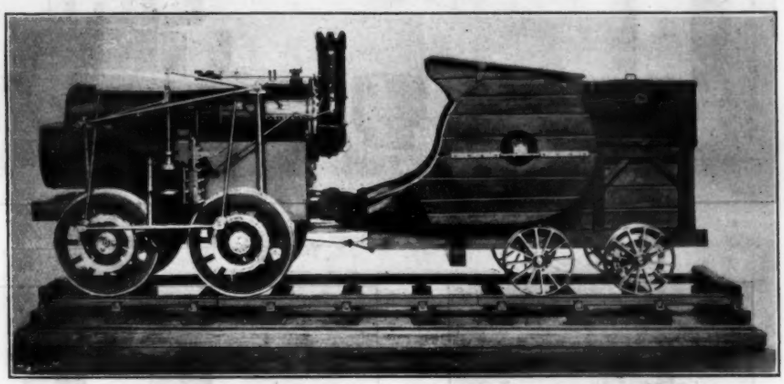


FIG. 9. MARC SEGUIN FIRE-TUBE BOILER BUILT IN 1827.

building materials, such as lime, cement, sand, plaster, ceramics, slates, paints, glasses, fireproofing material, &c. Section IV carries out tests on machinery (electrical machinery excepted) and machine accessories and fittings, such as boilers, hydraulic engines, pumps, internal-combustion engines, carburettors, fans, compressors, &c. Section V has charge of the study of comparatively unknown raw material, and of the chemical analysis of all the products, the examination of which falls to the other sections. The laboratory is further entrusted with the legal inspection of alcoholometers, areometers and thermometers connected therewith, used in sugar factories and in distilleries. The whole staff, as might be expected, are bound to secrecy. All tests made are paid for by a stated fee agreed upon by the Technical Committee of the Laboratory, in collaboration with the Governing Board and approved by the Ministry.

The safety-first department is a separate museum, which was instituted by a decree dated September 24, 1904; this is a permanent exhibition, of industrial safety devices and appliances. All apparatus and devices which cannot be obtained full-size or in the shape of models are represented by drawings and photographs. In order to demonstrate the efficacy of several of the safety devices, the machines they are connected with can be seen working. The space available being small comparatively for the number of exhibits available, the various working specimens are exhibited alternately. In this department, the exhibits are lent by and remain the property of the exhibitors, who can withdraw them at any time after giving a month's notice. On the other hand, the department, when the renewal of specimens requires it, reserves to itself the right to require any exhibit to be withdrawn in a month. The Conservatoire makes no charge for space, nor for the motive power required in connection with safety devices shown in connection with machinery in motion. An annexe contains a collection of safety appliances for use at sea.

As will be gathered from this brief description and from the illustrations, the materials for which were kindly supplied to us by the Director, Mr. H. Gabelle, and the Official Custodian, Mr. F. Guignard, the Conservatoire National des Arts et Métiers is a most interesting and complete institution, a unique one of its kind, in which the developments in the arts and crafts can be traced in their various phases over a long period, and one which at the same time affords most adequate aid to further progress.

THE BELLISS AND MORCOM STEAM TURBINE.

THE reputation of the firm of Messrs. Belliss and Morcom, Limited, of Birmingham, was founded largely upon the excellence of the steam engine they manufactured, and particularly upon the performances of the high speed engine with which their name has been so closely associated. The present generation of engineers takes the high-speed totally-enclosed forced-lubrication engine as a matter of course, hardly realising how great an advance it is beyond previous practice. It should not be forgotten that the type was originated by Messrs. Belliss and Morcom, Limited, and its commanding position amongst engines to-day is due more to their efforts than to the work of any other firm. When the steam turbine made its appearance as a commercial machine, it not only tended to limit the field of the reciprocating engine but, by reason of the size of the units which could be built, it opened up further possibilities for steam plant generally. Messrs. Belliss and Morcom naturally recognised both these facts at an early stage, and consequently they set themselves to manufacture steam turbines. It was in keeping with the traditions of the company that they did not commence as many other firms did by purchasing foreign designs, a practice which is not only detrimental to British engineering prestige but often proves very costly in the long run. They went to work to prepare designs of their own, confident that they could produce a machine at least equal to anything that could be built from imported designs, and one which should justify their own, and incidentally British, engineering capacity.

Relieved from the necessity of slavish imitation, and free to embody principles and to design details in accordance with their own views of the fitness of things, it was natural that Messrs. Belliss and Morcom should produce some interesting machines. They decided at the outset to build turbines of the impulse type, and among their earlier productions were exhaust steam turbines to work in conjunction with reciprocating engines. A notable installation of these machines was that at the Summer-lane power station of the Birmingham Corporation, where six 1,000 kw. turbines were put down to utilise the exhaust steam from the same number of 1,500 kw. triple expansion Belliss reciprocating engines. Although the engines were originally spaced only the normal distance apart, room was easily found for the turbines by bolting them directly to the top of the condensers, which thus formed the bedplates. Thus the capacity of the plant was increased by 66 per cent., and the overall economy materially improved at a much less cost than by any possible alternative. Two of the combined sets are illustrated later. Some 80 other exhaust and mixed pressure sets have been supplied by the firm, ranging from 150 kw. to 1,500 kw. rating.

Numerous ordinary fully-staged high-pressure sets, ranging from about 200 kw. to 10,000 kw., have also been supplied, and Messrs. Belliss and Morcom possess patterns covering the entire range by the conventional steps of output, all of which patterns have seen service. In addition, patterns and examples exist of small high-pressure sets down to 5-kw. capacity.

The fact that the firm are constructing turbines of such small sizes, in addition to those of larger output is interesting, in view of the controversy as to where the field of the reciprocating engine ends and where that of the turbine begins. The very definite statements sometimes heard as to the obsolescence of reciprocating steam engines of all sizes, or at any rate for more than very moderate outputs, often betoken a somewhat prejudicial standpoint. As a matter of fact no hard and fast line can be drawn between the provinces of the two prime movers, as local conditions and environment play so large a part in the question. Messrs. Belliss and Morcom, certainly lay down no fixed rule on the matter, but recommend whichever, according to their very large experience, is best suited for any particular case. Being large manufacturers of both kinds of prime mover they are entirely without prejudice in the matter, and as reciprocating engines as large as 750 kw. or 1,000 kw. are continually under construction in their shops at the same time as turbines as small as 10 kw. or 15 kw., it will be evident that neither type of machine has exclusive possession of the field.

Among their earlier turbines, the pair supplied to Johannesburg in 1910 are worthy of historical notice. These were high pressure impulse machines rated at 3,000 kw. at 1,500 r.p.m. They worked with steam at 175 lbs. gauge pressure, at a temperature of 540 deg. F., and exhausted into a vacuum equivalent to 27·8 in. with the barometer standing at 30 in. The general construction of these machines will be understood from the longitudinal section given in Fig. 1 on Plate XLIII. Fig. 2 shows a cross-section through the steam chest, and Fig. 3 a view of the rotor by itself. The outstanding feature of these machines is that they are of the disc and drum type of construction, the steam acting first on a velocity compounded wheel and then passing axially along a three-diameter stepped drum carrying simple impulse stages. There was, we believe, no precedent for constructing an impulse turbine of the land type with blades carried on a drum. Most designers feared that the necessary pressure drop between the successive stages would result in excessive leakage along the drum, and therefore avoided any such possibility by carrying

BLADINGS FOR STEAM TURBINES.

CONSTRUCTED BY MESSRS. BELLISS AND MORCOM, LIMITED, ENGINEERS, BIRMINGHAM.

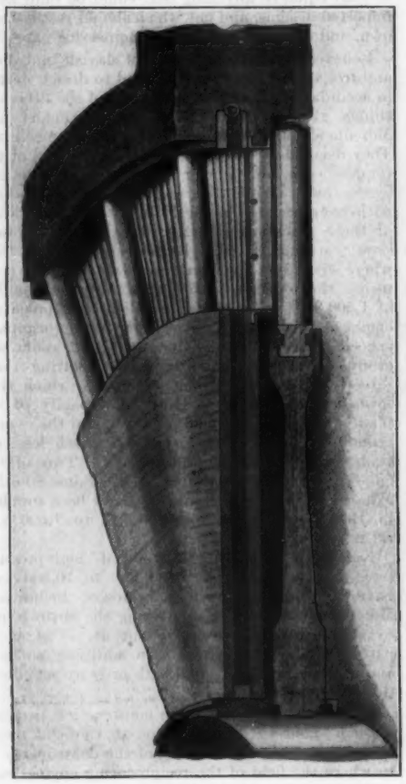


FIG. 7.

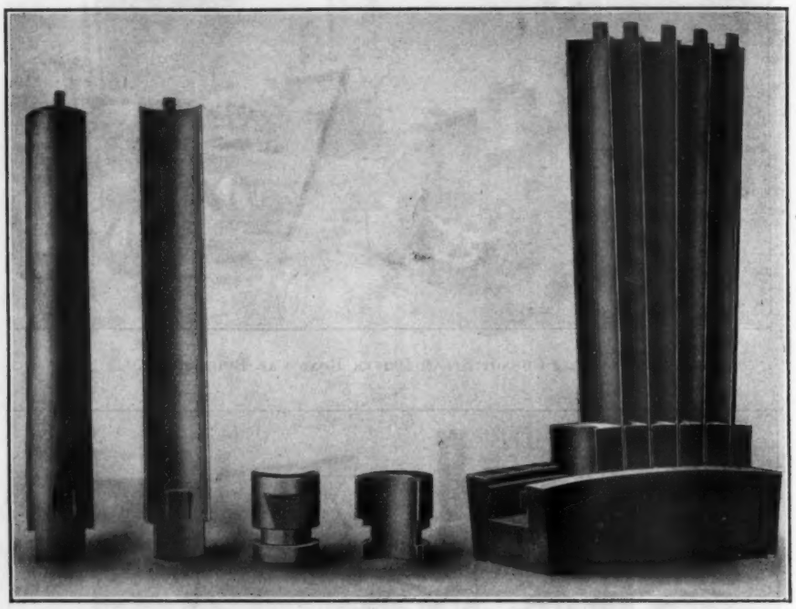


FIG. 8.

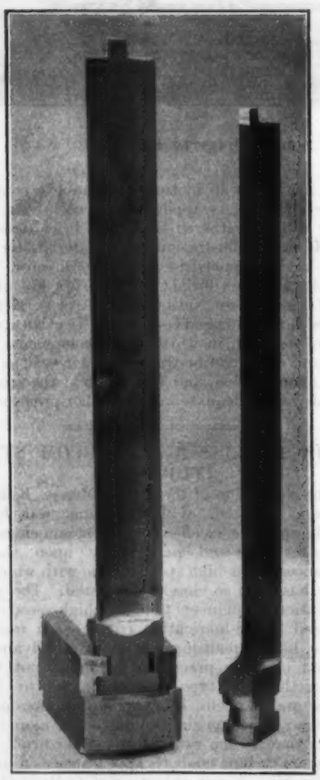


FIG. 9.

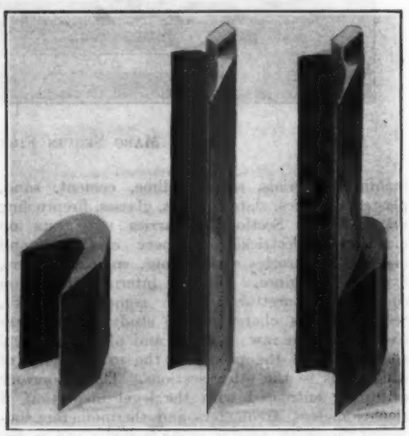


FIG. 10.

each running row of blades on a separate wheel so that the inter-stage leakage area was reduced to the clearance round the periphery of a comparatively small shaft. For slow-speed machines, such as the ones in question, the drum construction has certain very practical advantages. It permits a large number of stages to be got into a comparatively short machine, with a consequent reduction of the pressure drop per stage as compared with machines of the wheel type. This not only minimises interstage leakage, but by producing low steam velocities through the nozzle blades, enables the turbine to be built of small diameter for a given speed of revolution. Balancing against end-thrust has, of course, to be provided for in most turbines of the drum type, and this was effected in the Johannesburg machines by dummies similar to those employed in reaction machines. As evidence that the drum design of impulse turbines may be compatible with high efficiency, it may be stated that the official tests of the two machines in question showed efficiency ratios of 69·3 per cent. and 69 per cent. respectively on full load. A third machine of the same type, installed in 1912, had an efficiency ratio of 70·6 per cent. These figures are rather better than could be obtained by the majority of contemporary machines of similar size.

The chief constructional features of the machine will be understood from the drawings. An end-piece attached to the high pressure end of the turbine shaft carries a double-threaded worm, which drives a cross-shaft beneath it. This cross-shaft drives the oil pump as shown, and the governor and tachometer through bevel gearing. The pump is of the simple reciprocating valveless kind used by Messrs. Belliss and Morcom for many years for the forced lubrication of their engines and air compressors. Beyond the worm is the arrangement for locating the rotor endwise in the casing. This is a Michell double thrust bearing, a pair of flanges keyed to the spindle working against thrust pads housed in the ends of a sleeve through which the spindle runs. This sleeve is normally held fixed against rotation, but it is mounted on a bearing and provided with ball thrust bearings. In the event of excessive friction occurring between the spindle and the thrust rings, a small pin is sheared, and the inner sleeve rotates, the ball-bearings then taking up the thrust. This design was for the early days of the Michell bearing before it had quite proved itself, and, as it happens, did actually save the situation on more than one occasion. The shaft is packed, at both the high pressure and low pressure end by carbon packing rings working on renewable steel bushes pressed on to the shaft.

With the improved reliability of the 50 cycle alternator at 3,000 r.p.m., and the disappearance of the direct-driven turbo dynamo consequent upon the development of gearing, the field for slow-speed turbines in sizes up to about 5,000 kw. has practically disappeared. With the higher speeds the drum type of construction ceased to have the advantage, and Messrs. Belliss and Morcom therefore developed a series of machines in which the rotors consisted of a series of independent wheels, thus coming into line with what is considered orthodox practice. We understand, however, that something like seventy machines of the drum type have been installed with consistently satisfactory

STEAM TURBINES.

CONSTRUCTED BY MESSRS. BELLISS AND MORCOM, LIMITED, ENGINEERS, BIRMINGHAM.

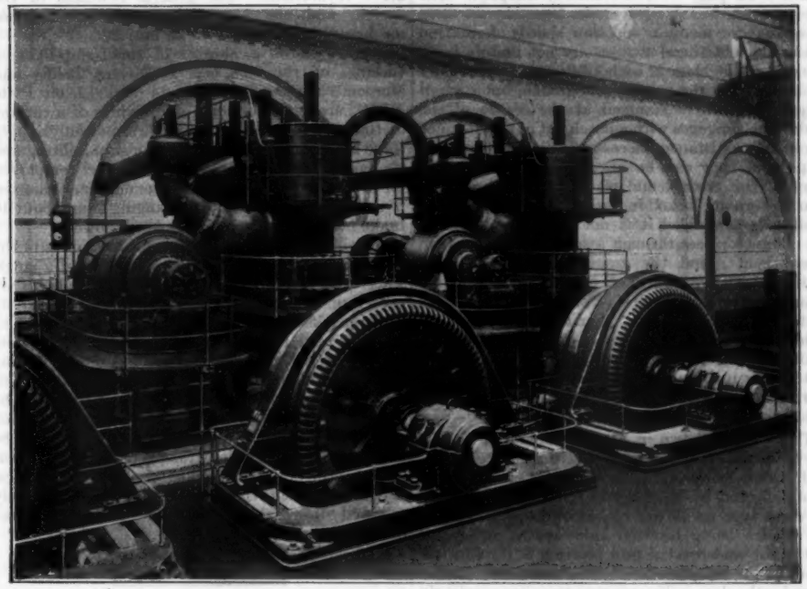


FIG. 11. 1,000-KW. EXHAUST STEAM TURBINES ADDED TO 1,500 KW. BELLISS ENGINES.

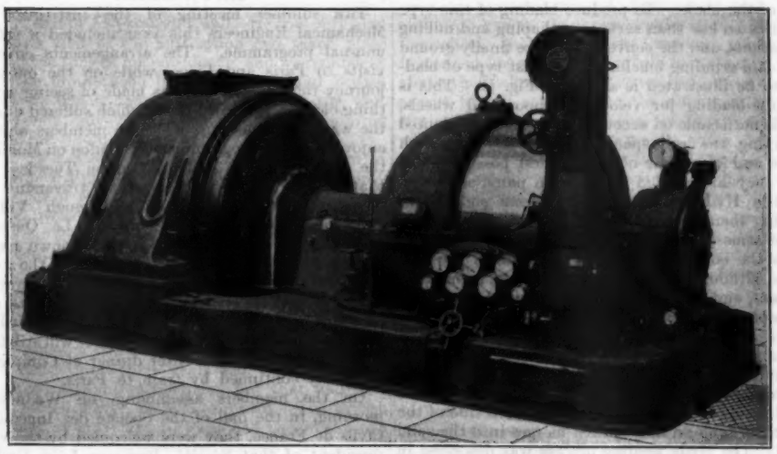


FIG. 12. 2,500-KW. 2,400 R.P.M. HIGH PRESSURE SET, SUPPLIED TO NORTH BROKEN HILL.

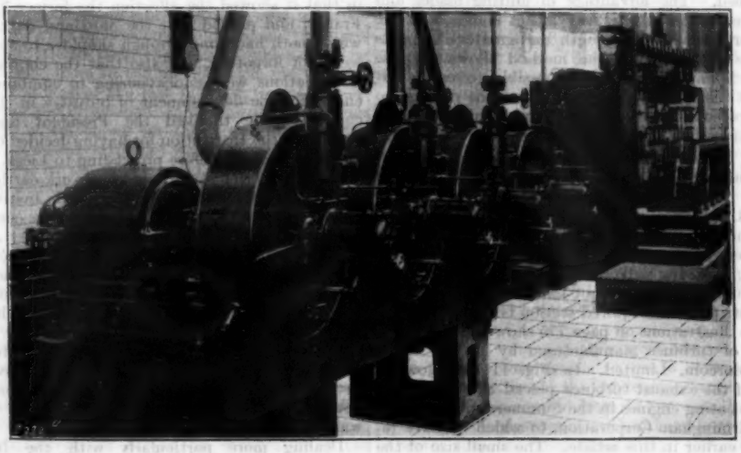


FIG. 13. 15-KW. 3,000 R.P.M. SHIP-LIGHTING TURBINES ON TEST BENCH.

results, and although the design is admittedly inapplicable to the higher speeds now general, the drum type would still be recommended by Messrs. Belliss as the most efficient and mechanical form of construction for certain conditions of steam pressure, power and speed. Indeed, the advent of still higher speeds, dictated by fashion or facility as may be, may see what is practically a reversion to type in the form of a stout shaft, which feature is still common with reaction turbines. In developing the wheel-type of turbine, the firm originated their own practice with regard to details, and thus kept themselves free from any obligation to foreign patentees. Several constructional features thus distinguish their turbine from its competitors, and although its external appearance is generally similar to that of all other impulse machines it reflects British more than Continental practice in its mechanical features.

Fig. 4, Plate XLIII, shows a longitudinal section through a 2,000 kw. B. and M. steam turbine, the same design being applicable to machines from 1,000 to 4,000 kw., although of course the relative proportion of the parts varies somewhat with the different sizes. The employment of the compound wheel is also subject to the conditions of pressure vacuum and speeds. The bedplate is continuous, and embodies an oil reservoir at the steam end, the oil draining from the bearings through a channel in one side of the bedplate. The oil pump is of the single or double helical gear type, single helical gear being usually preferred as it is found to run more sweetly. The pump is driven through a flexible coupling of the same type as the main coupling between the turbine and the generator, a type which adjusts itself easily and automatically in an axial direction, and permits a certain want of alignment as well. The attachment of the pump, it will be noted, is not to the bedplate, but to the governor-box, so that it moves freely with the latter as fore and aft creep may require. In turbines of larger sizes, 5,000 kw. and upwards, the pump drive is through a universal joint with joints lubricated under pressure.

The steam chest, in the case of medium sized turbines, such as those under consideration in which the first stage consists of a velocity compounded wheel, is formed in the lower half of the casing only. It is admitted that the practice of putting the steam chest on the top half of the casing has the advantage that the nozzles are more easily inspected, but Messrs. Belliss and Morcom consider that the balance of advantage lies with the practice they adopt. It is rarely that there is any need for the examination of the first set of nozzles, and to do this the turbine has to be opened, whichever plan is adopted. Should the nozzles be in the bottom half, they can only be examined by lifting out the rotor, but this is a small matter, and as a set-off against it, is the fact that no high-pressure steam joints have to be broken.

Fig. 5, on Plate XLIII, gives an enlarged view of the nozzles and blading. The wheels, it will be noted, are not made with bosses on the shaft bridging the diaphragms, but are located in position and spaced by means of loose distance rings surrounding the shaft. This obviates any risk of a wheel-boss cracking should any accident bring the rotor in contact with the inner edge of a diaphragm. In case of such an accidental contact, the loose ring, if injured, can be readily renewed. A further considerable advantage of the design consists in the fact that the wheels are made from much simpler forgings, and indeed, for many machines forgings are dispensed with, and ordinary rolled steel plate is used for the wheels. For the smaller machines, with wheels up to 36 in. diameter, the material usually adopted for the wheels is plate of carbon steel having a tensile strength between 34 and 40 tons per square inch. In designs in which the working stresses in the wheels are somewhat higher, a similar steel having a tensile strength 5 or 6 tons greater than the above is employed, while for conditions obtaining in turbines similar to the 10,000 kw. 3,000 revolutions machine which will be illustrated later, the wheels are made from a 50-60 ton alloy steel. The soundness of forged wheels is often a matter of anxiety, particularly in view of the numerous disastrous bursts of large turbines which have occurred in the United States. If one

considers the method of forging it will be clear that the part most likely to be defective will be the rim, for the distortion of the metal will have been most severe round the periphery of the forging, while there is obviously a greater danger of the steel near the outer edge being worked in too cold a condition. In view of the stretching the peripheral metal has to undergo, it is reasonable to suppose that defects are likely to take the form of radial cracks or lines of weakness. Relying on this reasoning Messrs. Belliss and Morcom, when machining their turbine wheels, part off a complete thin ring from the outside, which ring will at once reveal any radial flaw that might otherwise escape the closest scrutiny. This method obviously affords as good an indication of the quality of the metal in the finished forging as it is possible to obtain, and brings under review the state of the metal around the whole of the circumference of the wheel. After all, soundness is vastly more important than a few tons up or down in the tensile strength. The practice also is to anneal or heat treat wheels after rough machining.

Details of nozzles and blading of various kinds are shown in Figs. 5 and 6, on Plate XLIII, and Figs. 7 to 10, on page 774. Referring to the diaphragm blades first, these are built up of drawn brass section very similar to the well-known reaction bladings having their outer and inner ends riveted to brass shrouding strips by which the segments of blading are held in position. The diaphragm does not depend upon the blades for its stiffness as is the case in designs where the guide blades are cast in position. Messrs. Belliss and Morcom make their diaphragms from rolled steel plate of the necessary thickness and cut out windows for the steam ways. The radial bars between the windows are machined to an approximately stream-line section, so that their presence interferes as little as possible with the flow of the steam to the guide blades. The solid steel diaphragms with homogenous radial bars across the steam belt are considered very much superior to the cast-iron diaphragms with guide blades of thin sheet steel cast in position, which are usually employed. The latter are structurally weak and are unstable under distorting forces on account of the obliquity of the blades. The Belliss and Morcom diaphragm blading thus has the advantages of being a separately made article; a nozzle passage of highest efficiency can easily be provided: it is removable for cleaning or renewal without scrapping the diaphragm, and last but by no means least, it can be made of that eminently satisfactory metal—brass, so that ordinary corrosion troubles do not exist. The methods employed for holding it differ slightly according to the size of the blading and other considerations, but Figs. 5 and 7 illustrate generally the principle.

Coming now to the rotor blading, several types are employed according to the conditions to be met, and with each type there is, of course, an appropriate method of fixing. Fig. 6, on Plate XLIII, shows a design of attachment for approximately symmetrical blading adapted for compound stage guide blades or moving blades where the centrifugal forces are not unduly high. The blades are cut from drawn strip of the requisite cross section, the upper end being left with a pip for the shrouding to be riveted on, and the root being shaped with a forked tang at the end. The groove in which the blades are to be fixed is dovetailed, and the blade, held in a special tool, is driven down into the groove over the wire laid at the bottom of the groove. This opens out the fork and fixes the blade securely in the slot, as shown in Fig. 6. The accurate spacing and setting of the blades is assured by a lower shrouding strip which lies over the top of the slot and through perforations in which the blade roots pass. This can be seen in position in Fig. 6. The method is, as will be seen, extremely simple, and it permits of the lightest possible blade being used, a consideration which, of course, minimises the centrifugal stresses to be withstood. For guide blading in a compound stage, where there are no centrifugal stresses at all, the system is admirably adapted. Under moderate centrifugal stress, however, it has been found entirely adequate for running blades, a brass blade 1 in. wide withstanding a pull of about 1,000 lb. before coming out.

For longer, and therefore heavier, blading, the systems of manufacture and fixing shown in Figs. 8 and 9 on page 774, are usually adopted. The former comprises blades made from drawn strip brass used for medium and slow speeds of rotation where the centrifugal stresses are not unduly high. The root of the blade is without dovetail or shoulder to engage with the sides of the groove, but a small projecting latch is stamped at the centre of the blade which engages with a notch cut in the distance piece. The distance pieces are made of such a shape that they can be inserted sideways at any point of the groove, and when rotated through a quarter-turn are locked in position. Thus when the blading is assembled it is not necessary to insert the distance pieces through a special gate, and then drive them round the groove to their ultimate position. The strength of this form of blading against centrifugal forces is, of course, limited to that of the latch in shear. For brass blading, 1 in. wide, the ultimate strength of the latch is about 4,000 lb., and as the actual loading rarely exceeds 600 lb. per inch as a maximum, there is an ample margin of safety centrifugally besides lateral rigidity.

The blading shown in Fig. 9 is characterised by the fact that there are no separate distance pieces, each blade being cut from the solid, and spacing being effected by the form of the root. As in the previous type no gate is required in the wheel rim, the blades being inserted sideways at any point of the rim and rotated into position. The illustration makes the details of the blade and groove abundantly clear. The construction is exceedingly strong, as the whole of the shoulder-area of the blade root is effective in withstanding the centrifugal pull of the blade. To produce blading of this type requires no less than seventeen shaping and milling operations, and the convex backs are finally ground in a cam-grinding machine. The last type of blading to be illustrated is shown in Fig. 10. This is impulse-blading for velocity compounded wheels, and is noticeable on account of the method adopted of fixing the root-spacers to the blades. Both blade and spacer are of the simplest possible form, and they are welded together in pairs, as shown, by the Hyde process. This process consists in uniting them by means of copper which is melted in an atmosphere of hydrogen. Under such conditions the copper flows perfectly between the surfaces, although they may nominally be in metallic contact, and makes a joint which cannot afterwards be separated even by heat, except in an atmosphere of hydrogen itself. Although the process has a superficial resemblance to brazing, the result is much more in the nature of a weld, as microphotographs show that the copper permeates the steel for a considerable distance on each side of the joint, forming an alloy which merges into the solid steel. The Hyde welding process was described in ENGINEERING on September 2, 1921, page 338, when microphotographs illustrating its effects were reproduced. The advantage of uniting blades and distance pieces in this way is not confined to the greater mechanical strength and greater cheapness of the method, but the method allows the use of sections it is almost impossible to carve out and at the same time enables the blade-passage to be tapered without involving awkward machining operations.

We would mention that Messrs. Belliss and Morcom are sole licencees for the application of Hyde welding to the manufacture of turbine blades. Blades of the more symmetrical form like those of Figs. 8 and 9 are also made in large numbers by the Hyde process, the solid cut type of Fig. 9 being adopted when the dies for some particular sections do not exist, or when stainless steel strip of the required section is not available.

The illustrations on page 775 show three different types of turbines manufactured by Messrs. Belliss and Morcom, Limited. In Fig. 11 are shown a pair of the exhaust turbines placed at the back of reciprocating engines in the Summer-lane station of the Birmingham Corporation, to which we have referred earlier in this article. The small size of the turbines and the compactness of the arrangement will be particularly noticed. The next illustration, Fig. 12, shows the general appearance of a medium size turbine with its alternator, the actual example being a machine of 2,500 kw. rated capacity at 2,400 revolutions. The general neatness of the design, and the accessibility of the governor mechanism and valves will be noticed.

Fig. 13 shows a number of small ship-lighting turbines on the test bed at Messrs. Belliss and Morcom's works, and Figs. 14 and 15, on Plate XLIV, are reproductions of drawings of a turbine of the type in question. The firm not only supply these little turbines extensively for ship-lighting and similar purposes, but they are also largely employed for driving boiler-feed pumps, condenser auxiliaries, &c. They are built in sizes ranging from about 10 brake horse-power to 80 brake horse-power.

As will be seen from Fig. 14, the turbine is of the simplest possible description, consisting of a single wheel with three velocity stages. Carbon glands are used round the shaft, which has in most cases only to be packed against atmospheric pressure. The bearings have ring-lubrication, and the shaft carries both a throttle-governor and an emergency tripping governor. The throttle-governor has hand adjustment for varying the speed of the turbine. The speed is indicated by a vibration tachometer which involves no mechanical driving arrangement. The whole turbine is efficiently lagged and has a neat appearance, and the simplicity of the mechanical features is such that the design will be easily followed from the illustration without further explanation.

(To be continued.)

THE INSTITUTION OF MECHANICAL ENGINEERS.

THE summer meeting of the Institution of Mechanical Engineers this year included a rather unusual programme. The arrangements covered visits to Paris and Liége, while on the outward journey the opportunity was made of seeing something of the regions in France which suffered during the war. For this purpose those members able to enjoy the whole programme left London on Monday, the 12th inst., for Amiens, and on Tuesday left that city by motor for Compiègne, traversing the devastated area and passing through Villers-Brettoneux, Chuignolles, Chuignes, Le Quesnel, Montdidier and other places of well-known name. At one point a halt was made to inspect the great gun captured by the Australians. The arrangements were most creditable to the organisers, and everyone was much interested in what was still to be seen of the havoc of the war which it will still take a long time to efface. After dinner at Compiègne the party continued by train to Paris.

On the members assembling, on Wednesday morning, in the hall of the Société des Ingénieurs Civils de France, they were welcomed by the vice-president of that Société, Professor Léon Guillet, who stated that the visit of the British engineers had for their French colleagues a particular value, in that it showed the affection the former had for France, and proved that the hard and dark years which both had gone through shoulder to shoulder were not forgotten, and also that the engineers of both nations were endeavouring to combine their efforts for the development of industry in the two countries. He thanked the President and the Council of the Institution for having decided to hold meetings in Paris before proceeding to Liége. Prof. Guillet then briefly referred to the work carried out by Dr. Hele-Shaw, the president of the Institution, and to the distinctions which had been conferred upon him. On the other hand, Prof. Guillet added, Dr. Hele-Shaw was a member of the Société des Ingénieurs Civils de France, and was therefore received among them both as a member of that Société and also as president of one of the highest technical institutions of Great Britain. Dr. Hele-Shaw was, further, welcomed by the Société as a great patriot, one who had taken a very active part in the work involved in the war with Germany, devising means of attack and defence in trench warfare, and other work for the Admiralty.

Dealing more particularly with the Institution of Mechanical Engineers, Prof. Guillet referred

to the Institution's Alloys and Corrosion Committees. The reports of both these committees were well-known of French engineers; they had all been reproduced or published in abstract in French, and a large number of them had initiated other work. There had thus been formed between the French and the British laboratories a link, which the war work had considerably strengthened. The necessity of immense quantities of munitions of all kinds led both countries to unite their efforts to produce rapidly and with complete certainty guns, projectiles, cartridges, powders, &c., besides those asphyxiating products which we were compelled to use also, since every means of annihilation appeared good to our common enemies. Every difficulty was overcome, thanks to a constant interchange of ideas and efforts between the two nations. "This collaboration of four long years of war time is written in letters of gold in the history of our industries," said Prof. Guillet, who added that "one result would be to lead numerous future generations to desire to work together, hand in hand, for the good of all, during the period of calm and prosperity which both our nations long for." During the war, both nations had the same anxiety and also the same hope; together they had triumphed. It was impossible that there should not remain therefrom the desire for a continued union of the two peoples. A guarantee of this continued union was afforded by the present visit of the Institution. In the name of the Société des Ingénieurs Civils de France, he thanked the Institution for this visit.

Mr. M. Laubeuf, the president of the Société, said he had not welcomed the Institution and had asked Prof. Guillet to do so because he thought he would have to be away from Paris; he had, however, been able to postpone his departure for a few hours. Prof. Guillet had said all that he (the speaker) wanted to say, and he had stated it well. He was very glad that the visit of the Institution had taken place during the time of his presidency, and was confident that the brotherhood between French and British engineers which had been sealed during the war, would not only be maintained unaltered during peace, but would last for ever.

Dr. Hele-Shaw, President of the Institution of Mechanical Engineers, thanked the French Society on behalf of the British members. He recalled the cordial welcome which had been afforded to the latter on the occasion of the meeting in the same hall eight years ago, when the same friendly feelings ruled between the engineers of the two nations. Former sentiments of antagonism had now passed away, and, he thought, probably greatly owing to the efforts displayed by King Edward VII. He also recalled a still earlier meeting in Paris which took place thirty-three years ago, when there was a certain amount of coldness, but that had long since passed, never, he felt, to return. The British members on travelling to Paris had passed through some of the French devastated regions; it was good that they had done so, for it brought before them the terrible effects which the war had had upon the country. This was the first meeting of the Institution outside England since the war; the members well knew what the welcome would be, and the words in which it had been expressed would always be kept before them in the record of the proceedings.

The minutes of the last meeting were taken as read, and the President then expressed the pleasure he had in welcoming on the platform M. Eiffel, whose admirable structure was still one of the most wonderful of the whole world. M. Eiffel was also the oldest honorary member of the Institution.

Feed-Water Heaters for Locomotives.

The first paper taken was the one having the above title, by Professor E. Sauvage, who read it in abstract. We reproduce it on page 801.

The discussion was opened by Sir Vincent L. Raven, who congratulated the author upon the clear way in which he had put before the meeting such an important subject. On his (the speaker's) railway, the North-Eastern, they had considered the matter and had come to the conclusion, like the author, that there was not sufficient room on locomotives for fitting an economiser in the smoke-box. He had experience with the Weir system and knew of other appliances referred to by the author. These were dependent upon the use of part of the exhaust steam for raising the temperature of the water dumped into the boiler.

He preferred, after trials, the Davies and Metcalfe exhaust steam injector which, however, he did not think could be depended upon alone. A combination injector was needed in addition. The Davies and Metcalfe injector used exhaust steam supplemented by live steam, and could be used with live steam alone, but then did not give any economy. The economy was also dependent upon the human factor, *i.e.*, to what extent the driver would use it; it was, further, dependent upon the working of the oil separator, and if the latter were not kept clean, oil and impurities might find their way back into the boiler. One was then thrown back on the combination injector, and these injectors were also dependent upon the human element. It was well-known that in this case, as in others, actual practice differed from statements made in papers. In trials he had made with these exhaust steam injectors, the saving was about 5 per cent., but probably the drivers were not always using the exhaust injectors as exhaust injectors; this saving was a valuable one. The trials were made working passenger trains out, and goods back.

M. Herdner said that the Northern of France Railway used the Caille-Potonié heater, which they reported gave very good results, and hoped to obtain from it a saving of 10 per cent. This was a closed type apparatus with which the return of oil and impurities into the boiler was not possible.

Mr. T. C. Pulman thought that the paper by Professor Sauvage would lead to an investigation of many features hitherto unnoticed. In regard to the open type he (the speaker) believed that in actual practice temperatures of feed-water had been obtained higher than one would expect from a theoretical analysis of the various conditions. It was not his purpose to explain how temperatures above the boiling-point of water had been obtained except to call attention to the difference between static and dynamic conditions, the latter prevailing when a locomotive was running under full load and at full speed. Minute particles of superheated exhaust steam might be entrained through the condenser chamber, and only allowed to give up their latent heat when put under pressure by the hot water piston. An examination of this might lead to further interesting developments in the increased efficiency of locomotive feed heaters.

Over 200 installations of the open type of heater had proved that no troubles due to oil were necessary. In certain installations, the oil separator had been entirely done away with, and the oil in the 15 per cent. of exhaust steam, which was returned in the form of condensate, had no appreciable or detrimental effect. The use of the open type system could be recommended in all possible applications. In his conclusion 7 the author asked for more information in regard to what proportion of the heat received by the water was due to the exhaust of the engine apart from the exhaust of the pump. Tests had shown that with a Simplex or similar valve gear, less than 2 per cent. of the steam generated by the boiler was required to drive the pump under maximum conditions, and as the exhaust from the pump was used to aid the feed heating, a simple calculation showed that for every 100 lb. of water evaporated, 2 lb. would be diverted to the steam pump, and the heat from these 2 lb. in the form of exhaust steam would raise the temperature of the feed water a maximum not exceeding 20 deg. F. As the temperature of the feed water was within 8 deg. to 10 deg. F. of the temperature of the exhaust steam from the locomotive cylinder, it would readily be seen that the larger temperature rise was due almost entirely to the exhaust from the locomotive cylinders.

In actual tests in passenger service, it had been found advantageous to use a system which allowed the return of the condensate to the boilers, and as this represented from 12 per cent. to 15 per cent. of the feed water, cases had been known where a water stop had been eliminated; this allowed a reduction in the running time and a revision of the train schedule. The open type was as efficient six months after it had been put in service and left uncleaned as on the first day; that in itself was a strong argument in favour of the direct mixture of exhaust steam and water. Another advantage of the open type was that a minimum amount of the apparatus was under pressure, hence there was a minimum amount of trouble in connection with joints and other parts. The open type, further, owing to its integral construction, made it possible to equip existing locomotives which required an increase in capacity, or on which fuel economy required an improvement, without other change than tapping into the exhaust chamber and connecting up the water supply with the tank.

Major P. J. Cowan said it was difficult to say much that was new on the subject except in the way of describing the most recent appliances. Professor Sauvage's paper dealt with present-day applications, which covered part of what he (the speaker) was hopeful enough to believe would ultimately prove a considerably wider field. So far as present practice went he thought Professor Sauvage's paper corroborated the case put by Mr. F. H. Trevithick and himself before the Institution in 1913. He was a little surprised that the author had referred to articles in ENGINEERING which preceded the presentation of their paper to the Institution, and had omitted reference to the paper itself, though it was the result of more extended work and further study. That paper, as might be seen by the manner in which it had been compiled, attempted to focus attention on principles rather than to advocate particular devices. The principles still held true, and were to-day receiving more consideration than formerly.

He thought Professor Sauvage's conclusions might be accepted. Formerly, when coal was cheap, the margin for economy was not always considered great enough to warrant the cost of the feed-heating apparatus. To-day coal was more expensive, and the subject was much more attractive, even if it were not carried further than heating by exhaust steam. He considered that if properly worked out it was an advantage to withdraw steam from the blast for feed heating. He also thought that as regards flexibility of control, the independent pump feed had now been proved to satisfy the requirements of locomotive operation.

The author had referred to the remarks made by M. Maurice Lacoin in his report on the subject to the recent International Railway Congress at Rome. The corresponding reporter for English-speaking countries was Mr. G. J. Churchward, who said: "The advantages of hot feed where waste heat can be utilised are worth obtaining. The Great Western Railway system has resulted in about 8 per cent. economy of fuel, and very considerable improvement in the life and upkeep of the boiler." Major Cowan concluded that he thought a good many engineers who formerly regarded the question rather lightly, were now prepared to consider it for the latter reason alone.

In the course of his brief reply, Professor Sauvage asked to be excused for having, through an oversight, omitted to refer to the paper by Mr. Trevithick and Major Cowan. Now, what was required, more particularly in connection with locomotive feed-water heating, was to obtain the results of prolonged experience on all types and from every quarter. Some of the systems were by no means new, but they had been greatly improved, and it was not fair to institute a comparison on the early results only. Every apparatus should be judged upon what it could do at the present time. The remarks made, and others which would follow, would be published, and they would, he thought, be found valuable. He was glad his paper had given rise to an interesting discussion.

Electric Locomotives.

The second paper taken dealt with "Electric Locomotives," and was by Sir Vincent L. Raven, who read it in abstract. We reproduce it on page 795. In the course of his remarks, Sir Vincent added that he did not see why we should not have an electric locomotive, capable of running at speeds of from 25 m.p.h. to 90 m.p.h. The drawings he exhibited in the room showed how the motor control was obtained on the new North-Eastern

Railway locomotive, and the various combination secured. Trials had been made between Shildon and Newport with a train weighing 460 odd tons excluding the locomotive, formed of 17 vehicles, the grade being 1 in 103. The speed was 42 m.p.h.; the average draw-bar pull at that speed was 6·6 tons. On a gradient of 1 in 200, at 58 m.p.h., the draw-bar pull was about 4 tons. The average draw-bar pull for the whole distance, 18 miles, the rise being about 400 ft., was nearly 5·5 tons. It had never been possible to obtain anything like such results from a steam-driven locomotive, and when the main line was equipped for electric running, he believed that locomotive would do all that was expected of it. Railways were not able to spend much at the present time, and the electrification of their main line had had to be suspended; his electric locomotive had been finished before the track had been equipped. He (Sir Vincent) was therefore dependent upon the short mineral line he referred to in order to make his tests, but he repeated his opinion that when the main line was fitted up, the locomotive would give complete satisfaction. He thought ultimately there would be fewer designs required for the traffic with electric traction than with steam.

The President expressed the view that full justice could not be given the paper at the Paris meeting, adding that a joint meeting with the Institution of Electrical Engineers in London might perhaps be arranged.

M. M. Lacoin said the Paris-Orléans Railway Company was at the present time making trials with electric locomotives, and had ordered 200 such locomotives for goods service. These were of the two-bogie type which the company thought was the standard type for that service. He followed with great interest the tests for passenger service made by Sir Vincent Raven on the Shildon-Newport line, and regretted that those tests could not be made on a longer line. The company had the same problems which confronted Sir Vincent, and had considered three types, one gearless, one with connecting rods, and one with geared motors of the quill type, but had not considered it necessary to test the latter as the North Eastern Railway was doing useful work in that direction. The company however was ordering two types, the gearless and that with connecting rods. The engines were of 3,000 h.p. to 3,500 h.p. When the engines were tried, comparison would be possible with the engine referred to by Sir Vincent and would save the company the cost of experimenting with a type like the one mentioned in the paper. He asked Sir Vincent with reference to the goods engine for which two bogies are adopted, with buffers on the bogies and an articulated body, whether there was reason for thinking that for such powers as were required in Europe it was necessary to have the buffers on the bogies. The Paris-Orléans Company adopted buffers on the body of the locomotive; it was thought that this arrangement was simpler. The necessity of having the buffers on the bogies was not quite clear.

Professor F. C. Lea questioned the author's two figures of costs, viz.:—£103 per year per electric locomotive for repairs, inspection, preparing, cleaning, &c., and £610 for the same class of work on a steam locomotive. In an electric locomotive there were only driving parts, and these should be compared with the cylinders and gear of a steam one; or in the case of an electric locomotive, the costs at the station and on the transmission line should be added. Sir Vincent did not greatly emphasise the value of electrification in freight service, and he (the speaker) thought we should not overlook the very great importance of the freight traffic on railways. The height of the centre of gravity was important, and that had to be taken into consideration. A locomotive having a comparatively low centre of gravity was liable to have a violent motion. The author had also dealt with the question of the deadweight on wheels and had said that the importance of keeping this down had been overestimated, but this was a question to be considered from the point of view of keeping down charges in connection with the track, &c. This was an important point for civil engineers, who demanded that the deadweight should not exceed a certain given amount, on bridges, &c. All the conditions necessary for arriving at a greater tractive force could be met with the electric locomotive, but not in the steam-driven machine without adding a greater load; this was important also, and the real hope for future developments lay with the electric locomotive.

Mr. L. St. L. Pendred thought an impression might perhaps be created to the effect that Sir Vincent was entirely an electric man; that was not the case, for he was still a believer in the future of the steam locomotive for certain purposes, and was now engaged in the construction of a steam locomotive of considerable power, which would prove a very remarkable one in its way. He (the speaker) hoped that it would be possible ultimately to compare this machine in operation with one of Sir Vincent Raven's electric locomotives.

In the course of his reply, Sir Vincent L. Raven thanked M. Lacoin, of the Paris-Orléans Railway, for his remarks. He (the speaker) was trying one of the three types, and M. Lacoin the other two, and he invited M. Lacoin to England to see his work. M. Lacoin said he would be very glad to take advantage of this invitation, and hoped also to see Sir Vincent at the Paris-Orléans electric engine trials.

In regard to putting the buffers on the bogie frames, Sir Vincent continued, this appeared to be the better place, owing to the heavy loads and buffing stresses which arose with loose coupled goods trains. There was a stronger buffing support on the bogie frame than on the engine body. With reference to Professor Lea's remarks in regard to costs, £103 as against £610, the present paper was one on the designing of electric lomotives. He (the speaker) read last year a paper on the electrification of railways before the North East Coast Institution of Engineers, and in that all the questions had been dealt with. Professor Lea was right if he compared the cost of working electric locomotives with that of working steam locomotives; the cost at the power station and so forth had to be considered. His (the speaker's) views would be gathered by reading the two papers together. The centre of gravity was an important feature; it had to be reasonably high on railways. In the electric locomotive in question the driving wheels were 6 ft. 8 in. in diam. The electric motors were above the wheels, and the centre of gravity was as high as that of steam locomotives in England. The weight on the wheels could be distributed better in electrical machines than in steam engines. He had 20 tons on each axle, and the weight per foot run was what was commonly allowed. He thanked Mr. Pendred for his remarks and was obliged to him for making it; he had not put the steam engine on one side. When electrification of the lines had been carried further very complete tests of both would be undertaken.

Dr. Hele-Shaw called attention to the friendly way in which Sir Vincent and M. Lacoin proposed to exchange their experience, and the Institution would look forward to this exchange of information. The question of electric locomotives was, he hoped, going to be more completely discussed in London, and he hoped their French colleagues would then be present in large numbers. Seeing that the first president of the Institution was Stephenson, and that the present year marked the 75th anniversary, it was very fitting that they should have had papers on recent developments in locomotive practice at the present meeting.

Mechanical Vehicles and Road Surfaces.

The third paper taken at the meeting on Wednesday, the 14th inst., was one having the above title, by the Right Hon. Lord Montagu of Beaulieu. It was read in abstract by the secretary. We shall reproduce this in a future issue.

This paper dealt with the effect of bad roads on mechanical vehicles, treating the principle influences on wear and tear under four headings, of which the author first took fatigue of parts due to vibration and shock. The second was the wear of moving parts due to shock and vibration effects; the third losses resulting from extra power required, and lastly wear and tear of tyres due to intermittent contact with the road surface. Having shown the interest which the vehicle designer and owner had in good roads, the author suggested that in order to relieve the roads the time had come for the heavier types to be carried on more than four wheels, while some cheaper form of road making was also necessary if the roads were to be brought up to the necessary standard.

The discussion was opened by Lieut.-Colonel T. M. Hutchinson, D.S.O., who said it was most important that there should be co-operation between the engineer in charge of designing the vehicles and the road engineer. Insufficient attention had been paid to the suspension of vehicles, the result being both damage to the vehicles themselves and to the roads also. The unsprung weight of the wheels and axles was a matter of great importance and should be reduced as much as possible. Experiments were now being made with aluminium road wheels, which weighed less than half the weight of cast steel wheels; this meant half the hammer effect. Some form of legislation was wanted to encourage design in the direction of low axle weight. The damage to roads caused by tractors and trailers was due both to the weight on the road and to the tractive effort. The latter was unavoidable; it was particularly noticeable in gradients. The use of trailers was beneficial in connection with the former only. A four-wheel drive, he thought, would have to be developed for certain classes.

Mr. W. H. Patchell thought the road question in Paris was a very serious one; traffic in the bad Paris streets must have a very detrimental effect upon the buildings. He asked for further information in regard to the author's statements of cost of roads per superficial yard. In America, in the country, concrete roads had been laid of so narrow a width, on account of the cost, that they had often broken up. It was hoped to improve that state of affairs as frontages were taken up. Cost was the essence of the whole thing. He thought 8 in. to 10 in. thickness of concrete necessary for heavy traffic.

Lecture on Photo-Elasticity.

On Wednesday evening a lecture was delivered by Prof. E. G. Coker on "Recent Photo-Elastic Researches on Engineering Problems." The President, Dr. H. S. Hele-Shaw, was in the chair, supported by M. Maurice Lauboeuf, President of the Société des Ingénieurs Civils de France. A large number of members of both the French and English institutions were present, as well as a number of ladies. We gave a summary of the portions of this lecture which have not hitherto been referred to in our columns in our issue of last week (page 756), and need not go over the ground again, except to state that the interest aroused was very considerable, especially when the effects of strain were illustrated by means of working models of wheels in gear, worm and worm wheels, the cutting action of the lathe tool, the effect of planing, and removing material by means of a milling cutter. A comparison was also shown of the effect of the shape of the English and French standard patterns of cement briquette. Professor Coker and his assistants are to be congratulated on the uniform success which attended their demonstrations, and the trouble which they had taken in getting all the necessary apparatus to Paris was greatly appreciated. Mr. Legros interpreted at frequent intervals.

At the close Dr. Hele-Shaw drew attention to the care it had been necessary to expend in order to make the demonstrations successful in Paris while M. Lauboeuf also expressed the appreciation, of himself and his colleagues of the trouble which Prof. Coker must have gone to. They had been extremely interested in the wonderful results obtained.

At the invitation of the Société, members subsequently partook of supper before dispersing.

(To be continued.)

The Research Association of British Motor and Allied Manufacturers.—At the annual general meeting of the above association, held recently, Mr. H. C. B. Underdown was elected president, and Sir Dugald Clerk, K.B.E., F.R.S., Lieut.-Col. J. A. Cole, O.B.E., and Dr. F. W. Lanchester, F.R.S., were elected vice-presidents. During the past year the association has carried out research on suspensions, reports of which have been issued or are now in hand. Investigations on carburation have been commenced, and research work on radiators is also in hand.

EXHIBITS AT THE INTERNATIONAL FOUNDRY TRADES EXHIBITION, BIRMINGHAM.

CONSTRUCTED BY MESSRS. JOHN MACDONALD AND SON, LIMITED, MARYHILL, GLASGOW.

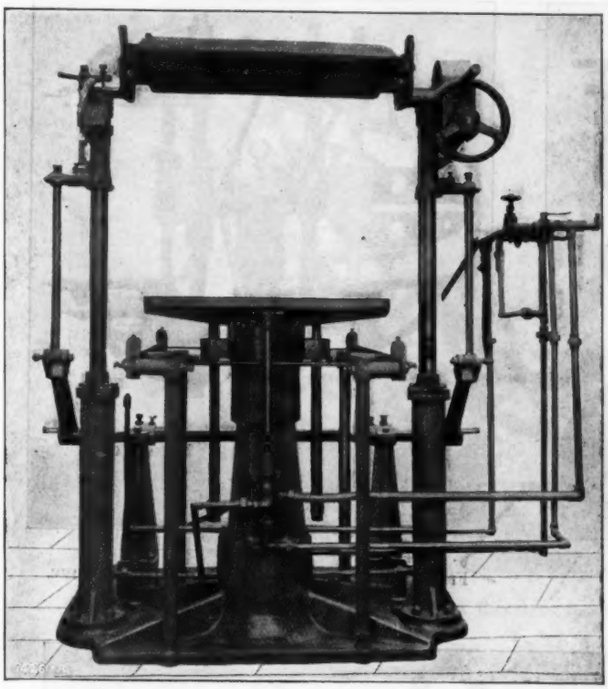


FIG. 1.

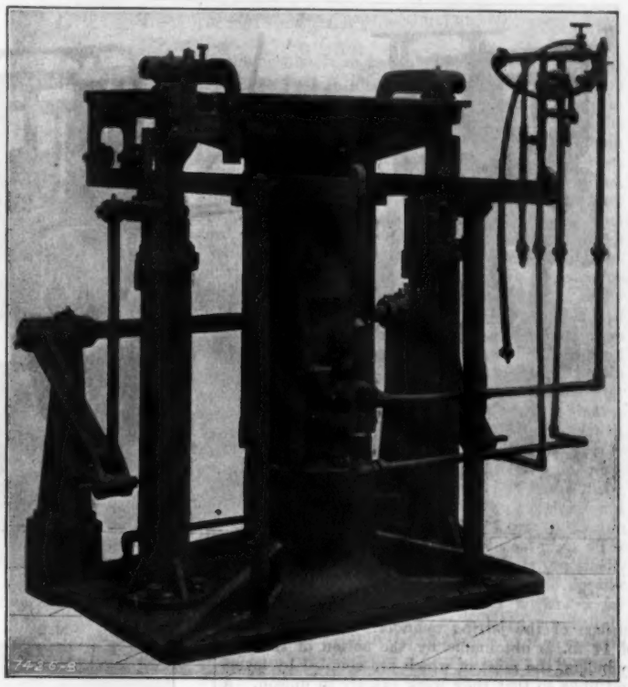


FIG. 2.

FIGS. 1 AND 2. MOULDING MACHINES.

FIG. 3.

FIG. 4.

FIGS. 3 AND 4. PNEUMATICALLY-OPERATED SAND RIDDLING MACHINES.

INTERNATIONAL FOUNDRY TRADES EXHIBITION AT BIRMINGHAM.

THE exhibition of Foundry Appliances and Products, which was opened on Thursday, June 15, in the Bingley Hall, Birmingham, by the Lord Mayor of the city, is thoroughly representative and interesting. It has been organised by the Birmingham Chamber of Commerce, in conjunction with the Institution of British Foundrymen and the British Cast-Iron Research Association, and is up to the standard which one has learnt to expect from the Birmingham Chamber of Commerce in view of the efficiency of their enterprise in connection with the British Industries Fairs. In addition to the main attraction of the stands of over a hundred exhibitors, there are lectures on foundry practice, daily exhibitions of industrial cinematograph films, and competitions in core-making, moulding and pattern-making for foundry employees and students. The interest taken in this latter feature is shown by the fact that for coremaking there are 85 entries, for moulding 120 entries, and for pattern-making 172 entries. The patterns sent in for competition are on view in the Minor Hall, while core-making and moulding are carried out by the competitors during the afternoons and evenings.

It is impossible to summarise the contents of the exhibition otherwise than by saying that they cover the whole range of foundry work. Cupolas, ladles, moulding machines of every kind, riddling machines, sand mixers, pattern and pattern-making machinery, castings, pig-iron, firebricks, crucibles, moulding sand, pyrometers and all the other necessary or useful appliances or materials are on view. Moulding machines are naturally very much in evidence, and range from the simplest type to machines of great size and complexity. It was stated at the opening ceremony that the machinery on view aggregated 1,000 tons in weight, and that between 300 h.p. and 400 h.p. was supplied for the working of the exhibits.

Messrs. John Macdonald and Son, Limited, of Watt-street, Maryhill, Glasgow, who are well known makers of pneumatic moulding machines working on the jolt-ramming principle, and other pneumatic foundry appliances, show an extensive collection of their products, among them being the moulding machines illustrated in Figs. 1 and 2, annexed. The former has a table measuring 36 in. by 26 in. and a lifting capacity of 9 cwt. It has a height of jar of 1¼ in. and gives the mould 140 jolts per minute when ramming. The jarring cylinder is 7 in. diameter, and requires for its operation 25 cub. ft. of free air per minute, the consumption of course only being at this rate during the very short periods when ramming is being effected. The impact of the jarring is taken by a thick fibre ring on the upper

EXHIBITS AT THE INTERNATIONAL FOUNDRY TRADES EXHIBITION, BIRMINGHAM.

CONSTRUCTED BY THE ADAPTABLE MOULDING MACHINE COMPANY, BIRMINGHAM.

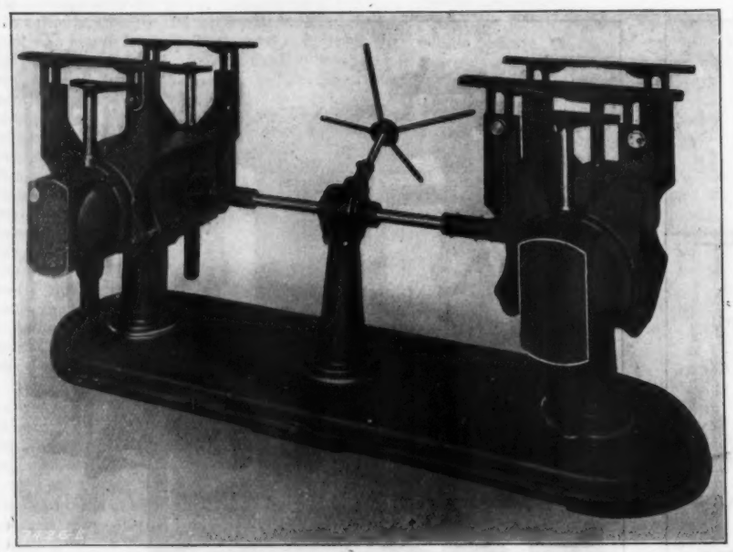


FIG. 5. COMBINED MOULDING MACHINES.

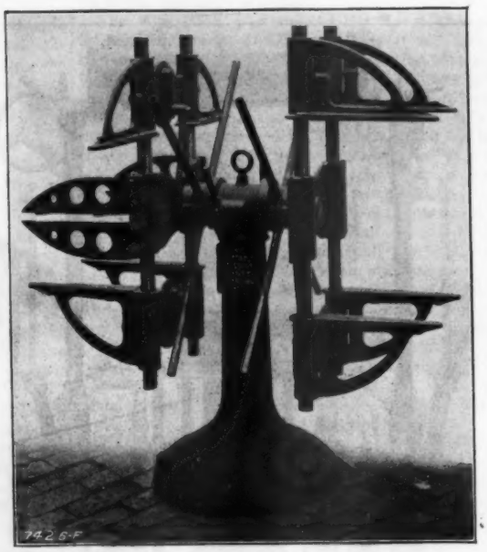


FIG. 6. DUPLEX ROLL-OVER MOULDING MACHINE.

surface of the jarring cylinder. A pattern draw of 14 in. is obtainable by the action of the side cylinders, the rams of which are coupled by levers and links so that they work exactly in unison. A special feature of the machine is that it is possible not only to draw the pattern away from the mould, but to keep the pattern plate stationary and draw away the mould from it, a proceeding which is frequently desirable. The complete machine weighs 33 cwt. The machine illustrated in Fig. 2 is of generally similar design, but somewhat smaller, its table measuring 24 in. square. The table is shown in its lowest position, resting on the top of the jarring ram. The ram in this case is 6 in. diameter with a 1¼ in. jolt. The lifting capacity is 1,344 lb. The machine consumes air during the jolting period at the rate of 17 cub. ft. of free air per minute and makes 160 jolts per minute. The pattern draw provided is 18 in., and the complete machine weighs 1 ton.

The air pressure used for both the machines is 80 lb. per square inch. This is furnished on the stand by a petrol-driven compressor of Italian make which is of interesting design. The four-motor cylinders and the two-compressor cylinders are cast in one block, one-compressor cylinder being at each end. The compressor displacement is 74 cub. ft. per minute, and yet the whole set complete with radiator weighs only 880 lb. Figs. 3 and 4 show two types of pneumatically-operated sand-riddling machines, also shown by Messrs. John Macdonald and Son, Limited. Fig. 3 represents a portable appliance, and Fig. 4 one attached to a column. The vibration of the sieve is effected in each case by a reciprocating air motor. The column type machine can be swung out of the way to either side, and this has the effect of automatically stopping it, which is a convenience to the workman when he wishes to remove the sand.

Among other exhibitors of moulding machines are the Adaptable Moulding Machine Company, of Stanmore-street, Birmingham. We have described the standard machines of this company fully on previous occasions. Fig. 5, above, shows two of these machines mounted on a single bedplate and operated together so as to produce in effect, a single moulding machine capable of dealing with pattern plates up to 8 ft. in length and necessitating a draw up to 6 in. The machine is adaptable from 12 in. to 20 in. in width, according to the requirements of the particular job in hand. Fig. 6 illustrates a Duplex "roll-over" machine exhibited by the same company. This is a new device which is particularly handy for certain classes of work. On each side of the central standard is a pair of columns which can be swung round on a vertical plane; sliding on the columns are pairs of adjustable brackets, which can be moved simultaneously to and from the centre by means of the long handles shown, the motion being obtained by a crank and connecting rod acting on each pair of brackets. The pattern plate and moulding box are placed on the lower pair of brackets and rammed by hand, the upper pair of brackets being meanwhile swung out of the workman's way. The latter are then put in position, both pairs closed on the work by the star-handles, the whole arrangement then turned upside down and the pattern withdrawn by separating the brackets again by means of the star wheel. The two sides of the machine can, of course, be operated quite independently of each other. An electrically-driven duplex sand sifter, made by the Adaptable Moulding Machine Company, is illustrated in Fig. 7, above. A small electric motor drives a countershaft which actuates a crank. The latter causes a rapid reciprocating motion of the double armed sieve bracket around the central column. The sieves are loose in their holders and thus get the rapidly repeated light shocks which assist the speed of riddling. An enclosed switch and fuse is mounted on the central column. The machine actually requires only 0·1 h.p. for its operation, but a 0·25 b.h.p. motor is fitted for the sake of robustness.

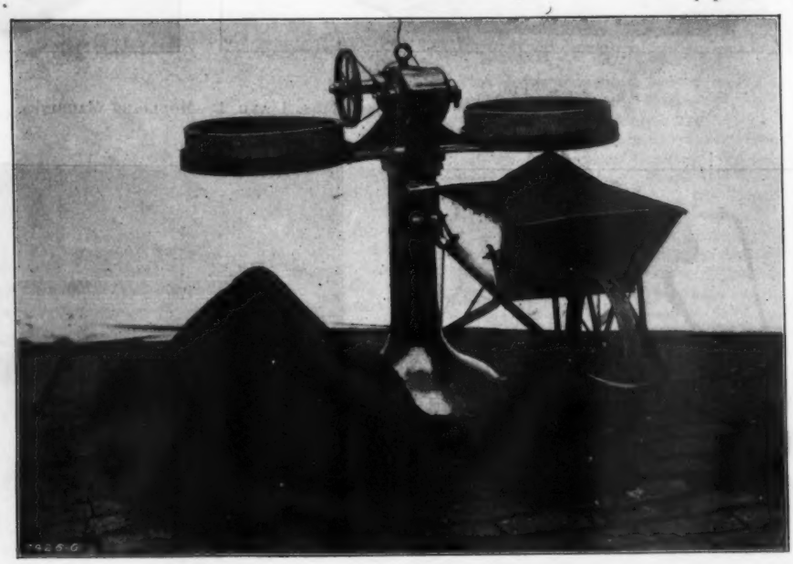


FIG. 7. ELECTRICALLY-DRIVEN DUPLEX SAND SIFTER.

Messrs. Thwaites Brothers, Limited, of Bradford

EXHIBITS AT THE FOUNDRY EXHIBITION, BIRMINGHAM.

CONSTRUCTED BY MESSRS. THWAITES BROTHERS, LIMITED, BRADFORD.

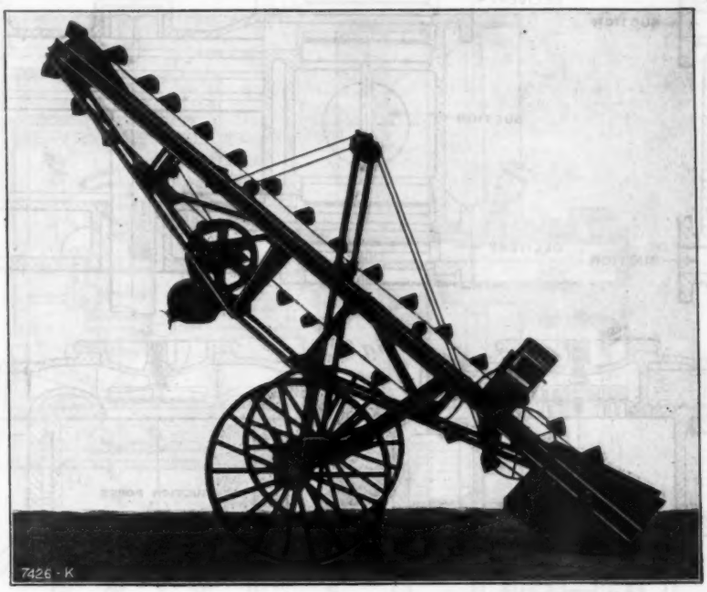
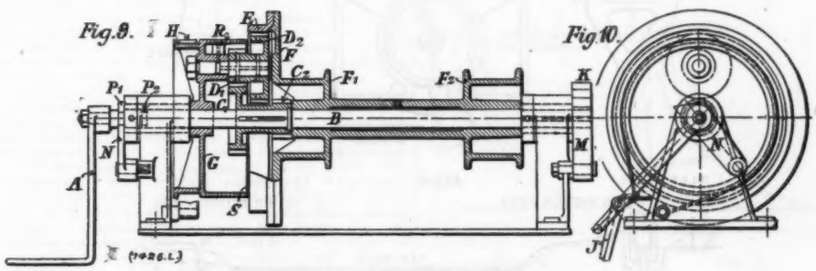


FIG. 8. PORTABLE ELEVATOR FOR HANDLING SAND, &c.



FIGS. 9 AND 10. HOISTING GEAR FOR CUPOLAS.

Yorkshire, who have one of the largest stands in the exhibition, show a very representative collection of foundry appliances, including cupolas with electric and hand-charging machines, ladles, blowers, tumbling barrels, &c. A portable elevator (Fig. 8), is designed for handling sand, ashes and rubbish in a foundry and loading them into carts or otherwise, but it is likely to find a field of usefulness in many other departments of a factory. Its construction is almost self-evident from the illustration. A light trussed girder is pivoted to a framing carried by a pair of wheels, and can be raised and lowered by wire ropes operated by the hand wheel shown. The girder carries sprocket wheels at each end, the upper one of which is driven by an electric motor, and the lower one is made adjustable for the purpose of tightening the pitch chain which passes over them. At short intervals along the pitch chain are fixed pressed steel buckets. The starting switch for the motor is mounted near the elevating hand wheel, in easy reach of the man using the machine.

One of the smaller cupolas on the stand is illustrated in Figs. 9 and 10 on the present page, and Figs. 11 to 18 on page 786, the last-named illustrations showing the hand-operated charging gear with which it is fitted. This gear does away with the necessity of a staging, and enables the cupola to be charged and manipulated by one man. The capacity of the cupola is 18 cwt. per hour, and its general design and main dimensions are shown in the illustrations. The bucket which raises the pig-iron and coke is fitted with two wheels only and is tipped by projecting fingers as it arrives at the top of the cupola. The hoisting gear for the bucket is shown separately in Figs. 9 and 10 on the present page. It is arranged to give two speeds of lift, a slow speed for the iron charges and a faster one for the coke. In addition to this feature it embodies an automatic sustaining brake, a non-reversing crank handle and a gravity return for the bucket.

The hoisting mechanism operates as follows: The crank handle A is keyed to the driving shaft B, which carries a double pinion C^1, C^2, the teeth of which drive respectively with the teeth of the double planet D^1, D^2, according to which set of gears is engaged. In the illustration the teeth C^1 are shown driving the teeth D^1, which in turn drive D^2, which gears with the internal rack E attached to the drum casting F carrying the drums F^1, F^2. Except when lowering, the drum G which carries the pin on which the pair of pinions revolve is held stationary by the brake H, which is applied by means of the weighted hand lever J shown in Fig. 10, so that when the crank handle A is rotated the rope drums F^1 and F^2 revolve and raise the bucket. If the handle is released at any point the weight of the bucket tends to drive the handle back, but this is prevented by the pawl M acting on a ratchet K secured to the end of the driving shaft B by a feather key. To lower the bucket the brake H is released by raising the hand lever J. When it is desired to raise a charge of iron the gear should be changed, and this is effected by raising the catch N from the recess P, in the shaft, drawing the shaft bodily forward until the teeth C^2 are in gear with the teeth on D^2 and dropping the catch N into the recess P^2. The gearing is lubricated by means of a grease lubricator R on the drum G. A steel plate S is fixed to the internal rack to retain the grease in the gear box. The whole gear makes a very simple, reliable and safe piece of mechanism and greatly lightens the work of the furnace man.

Magnesium is so new a metal for constructional purposes that it is probable that many engineers will see it for the first time, excepting in the form of ribbon for flashlight purposes, on the stand of the Magnesium Company, Limited, of 34A, Buckingham Palace-road, London, S.W. 1. Here are to be seen billets of several inches in diameter, rods, tubes, sheets and sections of many kinds. The company prepare the metal themselves in this country from ore derived from the Continent, the final process being the electrolisation of magnesium chloride. The metal is much like aluminium in appearance but materially lighter. Its lightness is really astonishing. It melts at 651 deg. C., which is half a dozen degrees below the melting-point of aluminium and can be cast without difficulty. A plain sand casting containing 94 per cent. magnesium is shown on the stand. The metal is said to be much superior in machining qualities to aluminium. It makes numerous useful alloys. A motor car piston, 92 mm. diameter, is shown on the stand. This is made of 89 per cent. magnesium alloyed with 11 per cent. of copper. It weighs only 11·56 ounces, as compared with the weight of 20 ounces for a corresponding piston made of the usual aluminium alloy and 33·5 ounces for one of cast-iron. The coefficient of expansion of magnesium is practically the same as that of aluminium, but the specific gravity is only 1·74 as compared with 2·7 for aluminium. It is likely that a large use will be found for the metal in the manufacture of extra-light alloys. It functions as a deoxidiser for aluminium, copper, nickel and steel are well known to foundrymen.

The Morgan Crucible Company, Limited, Battersea Works, London, S.W. 1, in addition to their standard types of crucibles, show some coated with a hard glaze in order to withstand the action of the gases. They also have plumbago crucibles produced by a newly-developed method of manufacture which are stated to give decidedly better results so far as heat transmission is concerned, a charge being melted in about three-quarters of the time, and with a corresponding reduction in fuel, as compared with the older type of crucibles. The life of the new type is also claimed to be longer. One of the most interesting of their exhibits is a series of hot plates, called "resisters," which can be maintained at any desired temperature up to 1,350 deg. C. They are of refractory material, with a glazed surface, those shown being about 2 ft. long by 1 ft. wide, and about an inch thick. A zig-zag layer of carbon is incorporated in the surface, and is fitted with terminals into which a flexible electric conductor can be plugged. The temperature of the plates is perfectly uniform except round the extreme edges, and of course remains unchanged so long as the current is kept on. For temperatures below a red heat the life of these "resisters" is said to be indefinite, and even at much higher temperatures it is very long, as there is no possibility of the carbonaceous layer becoming detached from the base. For household and laboratory purposes they have numerous obvious uses, and they should find a large field for employment in the manufacture of ovens, furnaces and other apparatus as they seem thoroughly sound mechanical devices. The Morgan Crucible Company also show one of their well-known tilting furnaces, as well as an electric furnace for non-ferrous metals. In this the current flows through resistances material incorporated in the walls of the furnace, the electrodes being heavy bronze rings surrounding the furnace at the top and bottom.

Messrs. Necol Industrial Collodions, Limited (a subsidiary company to Messrs. Nobel Industries, Limited), of 62, London Wall, E.C. 2, are exhibiting a substance called "Necol Plastic Wood" which is really a sort of semi-solution of nitro-cellulose, made from raw cotton fibre. It is a mouldable material which hardens, on exposure to the air,

AIR COMPRESSORS.

Fig.1.

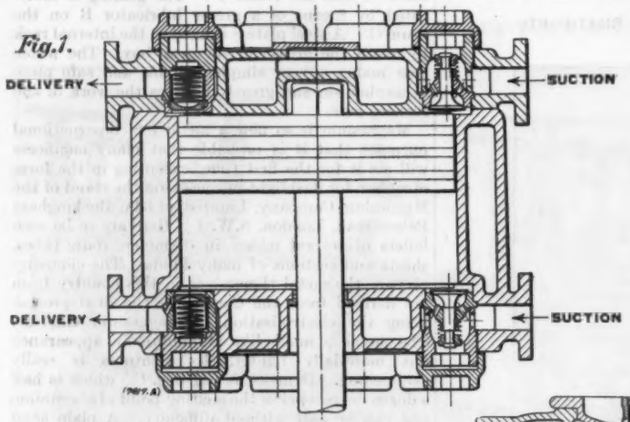
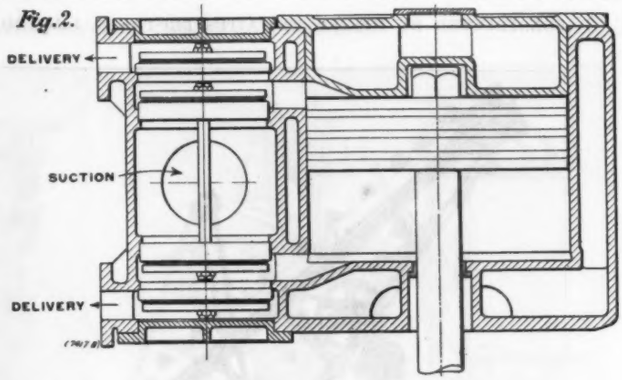


Fig.2.



into a tough waterproof substance. In connection with foundry work, it can be used to make into patterns, to mend patterns, or to serve as filleting. For the last purpose it can be just pressed into the corners of the patterns by the finger, like putty. It will stick to metal, and examples of metal sheets coated with it are shown, also a metal pinion with one of its teeth replaced with "Necol plastic wood" so that it can be used as a pattern. The stand also contained nice examples of decorative work carried out with the substance, which when moulded on to furniture and varnishes had all the appearance of wood carving in high relief. When dry, the material can be worked by ordinary joiners' tools and will take nails.

Messrs. Ritchie, Hart and Co., Limited, of Mount Pottinger Foundry, Belfast, show two special machines for foundry use, one a kind of portable digging machine for dressing up the foundry floor and the other a machine for making loam cores. The former consists of a heavy steel framing carrying at its lower end a broad wheel, the rim of which is fitted with digging buckets. At the top of the frame is a 3·5 h.p. electric motor which drives the wheel by means of enclosed worm reduction gear and a heavy sprocket chain. The whole machine is slung from the foundry crane and travelled about as required. The wheel digs up and turns over the floor to a depth of 12 in. and a scraper behind levels it again. Two men only are required for the operation, one on the crane and the other at the machine. The object of the machine is, of course, to save the time and labour otherwise expended in digging the floor by hand to make it ready for the next day's work. The core-making machine has a general resemblance to a long lathe. The head-stock, which is either driven by its own motor or from a countershaft, has four speeds. It will make cores from 1·5 in. to 16 in. diameter, and any length up to 13 ft., one man only being required to operate it. The cores produced on the machine are made truer and more rapidly than by the common hand method, and the cost of labour is substantially reduced.

Messrs. Joseph Baker, Sons and Perkins, Limited, of Kingsway House, London, W.C. 2, show a sand-mixing machine, built somewhat on the lines of the kneading and incorporating machinery with the manufacture of which the firm has been so long associated. The mixing arms which run in opposite directions, are fitted with renewable wearing strips, and similar provision is made in the chamber. The machine is provided with safety interlocking devices, so that it cannot be started unless the wire screen covering the mixing chamber is closed. For discharging, it tips automatically by power. The machine is made in various sizes, and it is claimed to make a thoroughly homogeneous mixture of a batch of sand in a very few minutes with a consumption of power materially less than required by edge runners and other types of mixers. The space occupied is also less.

A novel and interesting type of pig-breaker is to be seen on the stand of the United Brass Founders and Engineers, Limited, of Empress Foundry, Cornbrook, Manchester. It is the invention of Mr. Robert Temple, whose apparatus for driving studs into steel plates by the explosion of a small cartridge was described in these columns some time ago. The temple pig-breaker also makes use of cartridges. The pig is placed in the base of the device resting on a couple of knife-edges. Centrally above these is a cylinder containing a hammer weighing 5 lb. The top of the hammer is shouldered down and terminates in a tapered tang like a large twist drill. Normally the hammer is held up by the friction of the tang in a socket. To break the pig a small cartridge, like a 0·303 in. rifle cartridge without the bullet is inserted into a chamber which communicates with the space above the shoulder of the hammer. By pulling a knob the cartridge is fired, and the hammer is shot downwards a distance of 3 in. on to the centre of the pig. A 4-in. pig is unfailingly broken by the impact, with practically no noise or disturbance, indeed the breaker can be operated in an office. To raise the hammer a plunger with a socket at the end is pushed down on to the tang, and the plunger and hammer are then lifted together. It is said that one man can easily break one ton of pigs per hour with the device, which is quite portable, weighing only 230 lb. complete.

Fig.3.

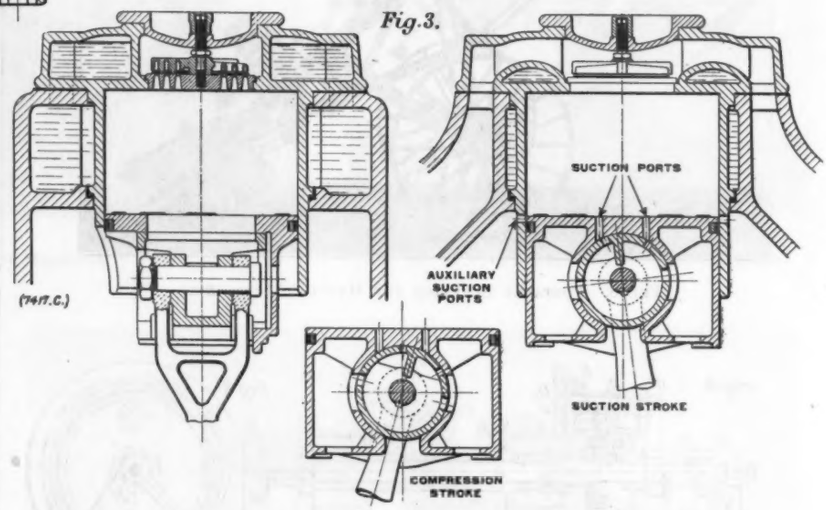
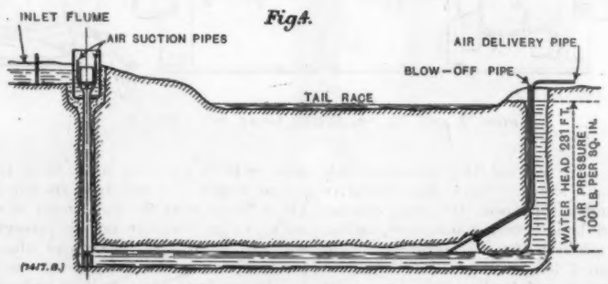


Fig.4.



(To be continued.)

AIR COMPRESSORS.*

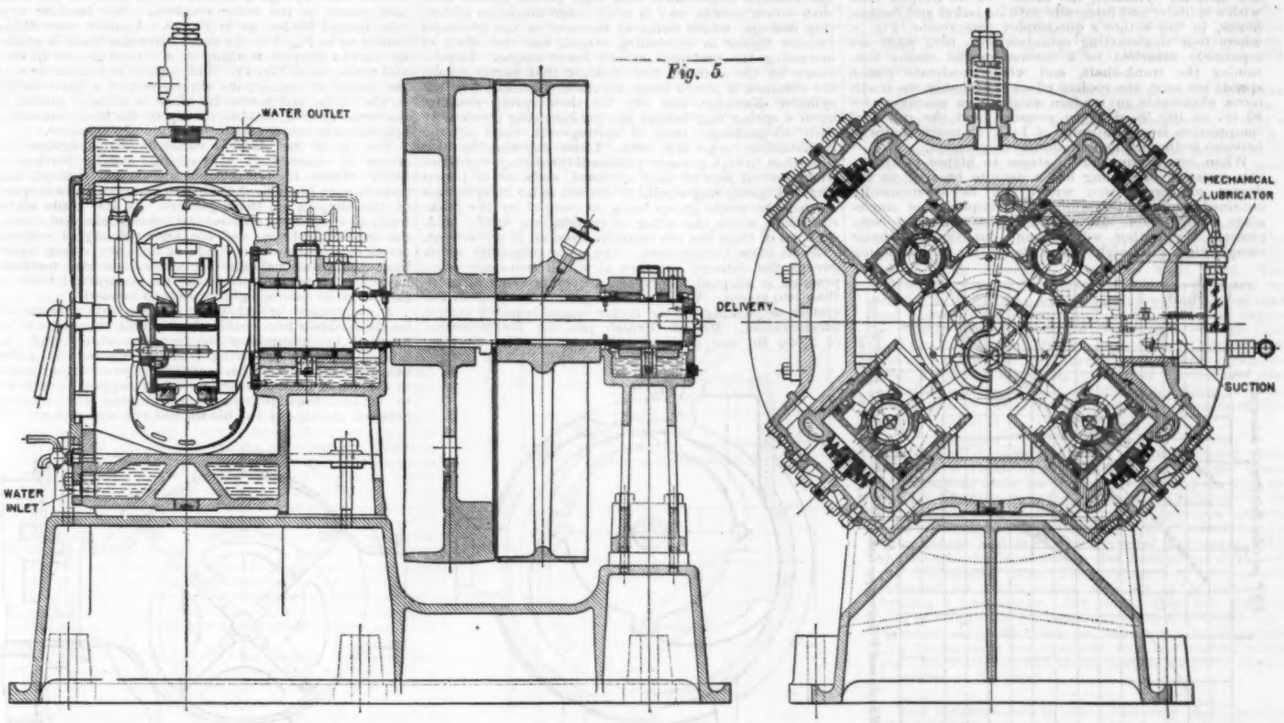
By WILLIAM REAVELL, of Ipswich, Member of Council.

THE title of this paper obviously covers a very wide field, for any machine which aspires air—at whatever absolute pressure—and compresses it, would be comprised in such a title. Hence, a vacuum pump is an air-compressor, aspiring rarefied air which it compresses subsequently and delivers to the atmosphere. The title consequently covers all vacuum pumps and exhausters; and includes blowers, which are designed to elevate air to a slightly superior pressure, while, on the other hand, it embraces machines having several stages or cylinders, which ultimately deliver the air at extremely high pressure. A machine which has to raise the pressure of air can be of the reciprocating piston type, or of the rotary type, including turbo-compressors, which Professor Rateau described in a paper at the Civil Engineering Congress in London in 1907, and which have been made in increasing numbers and sizes since then. At that Congress, the author dealt with reciprocating air-compressors in a paper,

* Paper read at the Paris Meeting of the Institution of Mechanical Engineers, June 14, 1922.

AIR COMPRESSORS.

Fig. 5.



setting out those features necessary to ensure high efficiency in such machines. In the present paper the author proposes to cover a wider field, and to deal with the features of different types of compressors which are required in each case to ensure that the most efficient results are secured.

The ordinary compressor or vacuum pump for normal use consists of a cylinder and piston actuated by a crank and connecting-rod or other forms of mechanism, and containing inlet and outlet valves for the admission and egress of the air. Figs. 1 and 2 show such a cylinder of the double-acting type, Fig. 1 being fitted with "mushroom" type suction valves and "thimble" type delivery valves, and Fig. 2 having plate valves. Fig. 1 gives the lesser clearance, but Fig. 2 the better cooling. A careful designer would have before him the following considerations:—(*a*) Clearance; (*b*) type of valve selected; (*c*) provision for cooling; and (*d*) form of piston-ring.

(*a*) *Clearance.*—The relation which the clearance volume bears to the cylinder volume, together with freedom from leakage in the piston-rings, are, neglecting temperature and valve resistance, the two factors which determine the ratio of the volume of free air delivered to the volume swept by the piston. The clearance volume is affected, not only by the allowance made between the end of the cylinder and the piston, but by the space required for the valve-pockets. The reduction of clearance to a minimum is not essential from the point of view of obtaining the lowest horse-power per cubic foot (or metre) of air delivered where the machines are fitted with automatic, that is, spring-loaded inlet valves. A designer might elect, for other reasons, to have a larger amount of clearance than the minimum possible, but this is done at the expense of increasing the diameter of the cylinder; the greater the clearance, the longer will be the return travel of the piston on the suction stroke before the air, which, in the previous stroke, has been compressed into that clearance, has expanded back again to just below atmospheric pressure to allow the suction valves to open. Obviously, therefore, with an increased diameter of cylinder, the same volume can be drawn into the larger cylinder as would be obtained in the smaller cylinder with the minimum clearance. With all spring-loaded suction-valves there must be a slight reduction in the absolute pressure of air aspired, due to the fact that the atmospheric pressure has to overcome the resistance of the spring on the suction-valve; consequently, in machines fitted with positively operated suction-valves, for example, a piston-valve, or with ports in the piston and gudgeon or "top end" of the connecting-rod (as in the author's quadruplex compressor, a cylinder of which is shown in Fig. 3) the maximum ratio of volume of delivered air compared with the volume swept by the piston can be obtained.

(*b*) *Types of Valves.*—In recent years the use of plate-valves of various forms has become common. In their design and in the choice of materials used, it is important to provide that the construction and lift shall be such that the valves will not crack or break on the one hand, and, on the other, that they will not deform so as to cause leakage of pressure air during operation. An early form of plate-valve was that

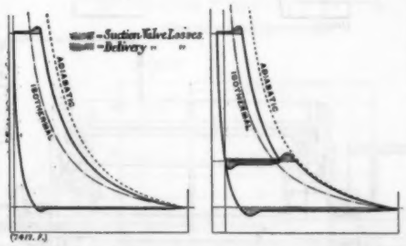


FIG. 6.

Single-Stage Compression.
Positively operated Suction Valves.
Automatic Delivery Valves.

Power per cub. ft. free air delivered = 0·202 B.H.P.
M.E.P. = 32·23 lb. sq. in.

FIG. 7.

Two-Stage Compression with Intercooling.
Automatic Suction and Delivery Valves.

Power per cub. ft. free air delivered = 0·202 B.H.P.
M.E.P. = 33·68 lb. sq. in.

introduced by Mr. Mathewson in 1895, in which a thin disk plate-valve was controlled by a form of curved flat spring, as commonly used in electric bell pushes, but having three points at equal distance apart, giving three-point pressure on the plate-valve. This was one of the earliest types to avoid the use of separate coil springs.

Valves of the Reed type, as used in motor horns, were made at, or before, this date, by Mr. Peter Brotherhood, a common arrangement being to arrange several reeds in a form of a star, the inner ends of the reeds being secured at the centre, and the projecting ends being free to open and close over the openings in the cover of the cylinder. The spring of the material was relied upon for the closing of the valve, but a guard-plate was fitted to limit the lift of the reeds.

The Rogler-Hoerbiger plate-valve has a multiple ported plate, which itself is provided with a flexible centre. In this construction the centre to the flexible plate is fixed, thus definitely guiding the plate-valve and providing a spring action, although this spring is reinforced with supplementary spiral springs, suitably seated in a guard. In some cases a thin steel cushion-plate is inserted between the plate-valve and the guard. In another form of Rogler valve, the valve itself is as described above, but instead of separate spiral springs, the spring valve-plate itself is reinforced by a strong stop-plate, having four curved spring arms giving four points where the spring pressure is applied to the outer rim of the plate-valve.

In the Simplate valve a series of concentric thin annular plates, each separately guided by the cover plate, are used, each concentric ring being controlled by small spiral springs seated in the cover plate.

Feather valve.—This type of plate valve consists of a series of ribbon steel strips of differing lengths so as to seat in a circular plate having slotted ports to correspond with the length and width of each ribbon steel valve. For this construction a valve-guard confines the ends of each ribbon plate, but the plate is free to lift in the middle to allow the air to pass in or out. The ends of each ribbon plate are free to slide and no additional springs are used.

(*c*) *Cooling.*—The problem of efficiently cooling a compressor cylinder and head is one which is extremely important, so as to ensure that the power absorbed in driving the machine is reduced to a minimum. Perhaps the only method of air compression which is used to-day in which isothermal compression is obtained is the hydraulic system used at Cobalt, Ontario, and similar installations, where a high vertical fall of water is used to perform the compressing operations. For those not familiar with this arrangement it might briefly be described as follows:—The water impounded at the top of the fall passes down a vertical pipe, and at the bottom flows into a chamber having a roof higher than the outlet of the pipe. Imprisoned air carried down by the water column is liberated in the underground chamber, and its pressure becomes that due to the head of water in the pipe. (Fig. 4 shows this diagrammatically.) An air-pipe carried through the roof of the underground chamber enables the air to be led away to the surface for use, and the tail-water rises to the lower surface level indicated and flows away.

In mechanically-operated compressors, while isothermal compression is the ideal to be aimed at, it cannot be attained. It is well known that the difference between isothermal and adiabatic compression is represented by the indices to the volume in the following formulæ:—

Isothermal compression $P v = C$.
Adiabatic compression $P v^{1\cdot41} = C$.

It is clear, therefore, that the closer the index of compression approximates to the isothermal, the more efficient will be the machine.

In compressors of the single-stage type, any reduction from adiabatic compression can only be obtained by the abstraction of heat through the cylinder walls and head, except in special cases where water is injected into a cylinder and subsequently drained away from the discharged air. Consequently, the amount of heat which can be abstracted depends upon:—(1) The diameter of the cylinder; (2) piston-speed (in other words, the "time" element); (3) whether the construction is single or double acting; (4) the thickness of the cylinder walls and head; (5) the amount of the cylinder head area which can be cooled.

A construction which would be rejected in steam-engine practice—because of the condensation which would be obtained—would, other things being equal, be an ideal construction for an air-compressor from the point of view of efficient cooling. In large double-acting compressors, with a high piston-speed and the thick cylinder walls demanded, very little reduction from adiabatic compression can be obtained.

In compressors of the single-acting variety, having one idle stroke per revolution, so far as work done upon

the air is concerned, the cooling will be better in multi-cylinder machines than in single-cylinder machines of the same total capacity. Where thin inserted liners are used for cylinders, the metal can be thinner than with a cylinder cast integrally with its jacket and flanges, hence, in the author's quadruplex compressor, Fig. 5, where four single-acting cylinders with thin walls are separately attached to a circumferential casing containing the crank-shaft, and where moderate piston speeds are used, the cooling effect is probably the maximum obtainable in modern single-stage machines for 80 lb. to 100 lb. delivery pressure, and the index of compression is of the order of 1·23, or nearly halfway between isothermal and adiabatic compression.

When compressing air in stages to higher pressures, this question of cooling has a definite bearing on the degree of compression which can be economically obtained while still retaining the simplicity of single-stage compression. In considering a two-stage compressor, the author would point out that adiabatic compression with high piston speeds for double-acting

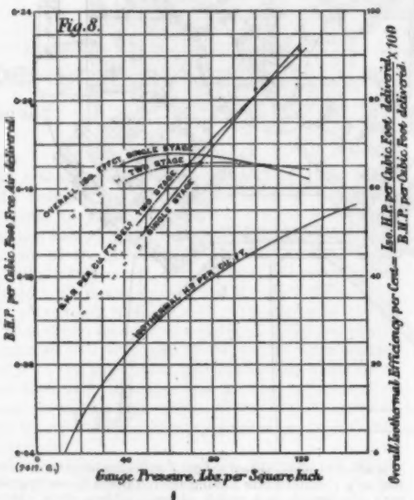


Fig. 8.
B.H.P. per Cubic Foot Free Air delivered
Overall Isothermal Efficiency per Cent.= Ins. H.P. per Cubic Foot delivered / B.H.P. per Cubic Foot delivered × 100
ISOTHERMAL
ADIABATIC
Gauge Pressure, Lbs. per Square Inch.

machines entails using two-stage cylinders for pressures for which that construction is not necessary when the cooling conditions are more ideal.

Fig. 6 shows a typical indicator card from a single-acting machine, the compression curve being constructed to the formula: $P_1 \cdot 1^{\cdot 25} = C$. Superimposed on it are dotted curves, assuming isothermal and adiabatic compression.

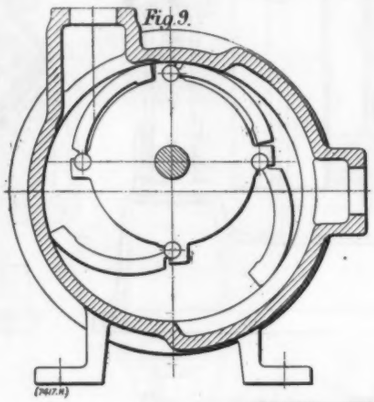
Fig. 7 shows compression carried out to the same delivery pressure in two stages in a double-acting machine, the air, after the first stage of compression, being cooled in an intercooler almost to the initial temperature, and thereby reduced in volume; the compression curve (in both the first and second stage) is assumed as $P_1 \cdot 1^{\cdot 35}$ as found in practice for high-speed machines of that type. The total area of the diagram is further increased by the fact that the delivery pressure in the first stage is higher than the intercooler pressure; and the suction pressure in the second stage lower than the intercooler pressure—by the resistance of the springs of the valves.

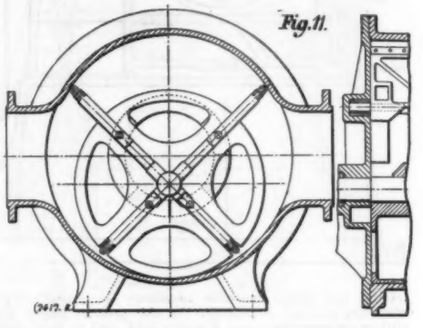
The results show that the total area of the single-stage machine (in full lines, Fig. 6) is less than the combined area of the two-stage diagram, Fig. 7, for the delivery pressure of 100 lb. for which the diagrams are made. The closer the diagram, Fig. 6, approaches to the isothermal, the higher is the permissible delivery pressure for which single-stage compression is justified. Hence, in the single-acting quadruplex compressor, single-stage compression can be used for higher delivery pressures than in double-acting machines of higher piston speed.

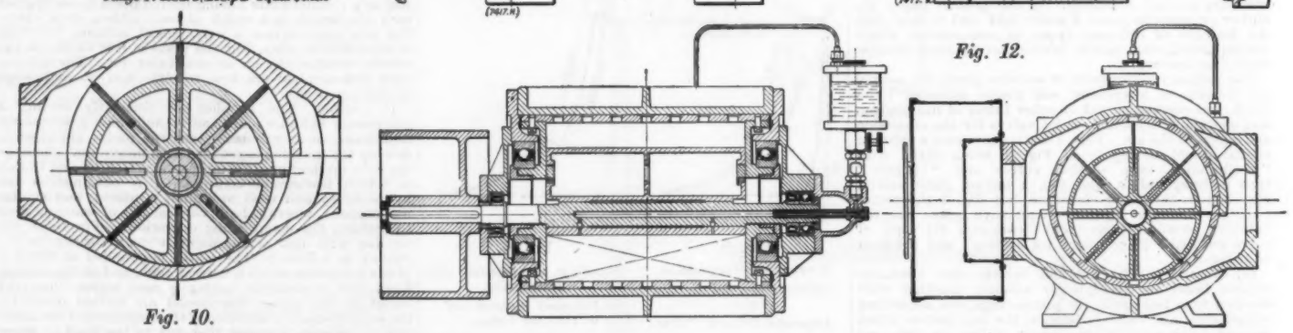
Fig. 8 is a graph which shows the actual performance of single-stage machines, and indicates that of two-stage machines of similar capacity deduced from the above data. The pressures at which the curves cross one another will be noted.

(d) *Piston Rings.*—The air tightness of piston rings has an obvious bearing on the volumetric efficiency obtained and also on the horse-power per cubic foot or metre of air delivered. Leakage past the piston rings being a function of time, tightness of piston rings is of less relative importance with high piston speeds than with slower speeds, and in multi-stage machines piston-ring leakage, which tends to increase as the pressures become higher in succeeding stages, has the effect of increasing the pressures at the lower stages. Experiments by the author's firm indicate that better results are obtained if piston rings, accurately machined to the cylinder diameter, can rely for their spring pressure upon a spring ring behind the packing ring (preferably with air-packing), than if sprung-over rings of the Ramsbottom type are used. These experiments also show that, in high-pressure pistons of three-stage machines when several sets of rings are used, each set of piston ring and spring ring should be carried in an independent carrier, the whole group being so secured by the junk-ring that, while the series of carriers are firmly held, each set of rings has the requisite freedom of movement.

Multi-Stage Compressors.—The same principles which govern the delivery pressure at which two-stage compression is adopted, apply also to compressors of more than two stages. When extreme pressures are used, the system of packing for the higher stages requires careful consideration. Modern British practice for pressures of 2,000 lb. and above usually provides for fibre or similar packing for the final plunger in the form of neck-rings, the plunger or piston itself being without packing rings, and accurately guided.







A notable instance of design for extreme pressures was given in the discussion on a paper by Mr. West at a joint meeting in London of the Institution of Mechanical Engineers and the Society of Chemical Industry, where the super-compressor, designed and made by the eminent French scientist, Professor Claude, of Paris, for 1,000 atmospheres pressure, in connection with his synthetic ammonia process, was described. In the final stage of this machine, the ground piston rod is packed with a hat leather, and cool working is ensured by making the plunger hollow, and supplying it with cooling water—an interesting solution of a difficult problem.

In multi-stage machines the practice in the construction of intercoolers has undergone a change, and the copper-coil coolers which were almost universal (and are still used in smaller machines of that type) are being replaced in large industrial compressors by straight tube intercoolers. Copper coils, however, are still used in the final stages of such machines.

Straight-tube intercoolers should preferably be constructed on the "counter-current" principle, and with the air passing through the tubes while the water surrounds them. Provision must be made for blowing off the water separated from the compressed air during cooling, and to provide that the air which may be separated out from the cooling water itself cannot form air-pockets which might impede the free passage of the cooling water.

Rotary Compressors.—Just as, since the days of the "Hero" engine, the rotary principle has exercised a fascination for inventors, and has led up to the highly efficient steam turbine of to-day, so have succeeding generations of compressor designers endeavoured to apply this principle. Amongst the many forms experimented with, the Crescent type is probably the most frequently used. In principle it consists of a rotor, the shaft of which is carried in bearings eccentric with the stator or casing, so that the path of any blade attached to the rotor sweeps a crescent form between the rotor and stator as the rotor revolves. One familiar type uses hinged blades, as in Fig. 9. Another uses sliding blades as in Fig. 10. In some cases the blade is guided by curved slippers working in a turned groove in each end cover, as in Fig. 11. This groove is concentric with the stator or casing; the slipper carries a pin attached to the blade, and hence the blade is suitably guided as the rotor rotates, so that the tip of the blade maintains approximate contact with the inside of the stator.

The tip of the blade is variously sealed against the stator by some form of packing, usually leather or fibre. Where high rotational speeds are desired, this form cannot be utilised, owing to the high surface speed of the slippers in their grooves. If the blade slides freely in the groove, without the use of guides and covers, its centrifugal force, and the high velocity of rubbing speed of the tip of the blade against the stator, again limit the rotational speed possible. Several methods have been used for restraining the centrifugal force of the blades to enable higher speeds to be used.

A compressor or exhauster of this type constructed by the author's firm enables high rotational speeds to be adopted by interposing between the stator and the blades a freely revolving cylinder carried on roller bearings (Fig. 12). The centrifugal force of the blades in this construction causes the freely supported cylinder to rotate, thus practically eliminating the rubbing between the tips of the blades and the stator in the old form, and, the cylinder being perforated with holes, air passes freely through the machine.

All of these types of machines, while adapted for low-pressure compressors and for exhausters, are not easily designed for high pressures, for two reasons:—(1) That the surface available for water cooling is not large compared with the volume of air passing through the machine; (2) that in all rotary machines of such general types, the delivery pressure projected on the whole surface of the rotor causes a considerable total load on its bearings. These objections have increasing force as the capacity for which the machines are designed increases.

Turbo Compressors.—Consequently, for large volumes, whether for low or high pressure, the turbo compressor, in connection with which Professor Rateau's pioneer work has already been noted by the author, is coming into increasing use. The evolution of the rotary compressor has been a very rapid one, and to-day the design and construction of this type has reached a fairly recognised standard practice.

A few years ago makers regarded a peripheral velocity of the rotor of about 500 ft. per second as a maximum permissible limit, but the present-day tendency aims at the adoption of higher speeds, which are rendered possible by the use of modern alloy steels. Peripheral speeds of 700 ft. to 800 ft. per second are now frequently met with. Such speeds produce a much higher pressure rise per stage, and consequently enable the designer to reach relatively high delivery pressures with few stages. Whereas a little over a decade ago 15 to 20 stages were required to produce a pressure of 100 lb. per square inch gauge, such as is common in colliery working, a modern turbo compressor will produce this pressure with about half this number of stages.

The diagram, Fig. 13, shows the relation between peripheral velocity and pressure ratio obtainable in a single stage turbo blower, when dealing with air at

normal temperature and atmospheric pressure at the inlet. From this it will be seen that if a tip speed of 900 ft. per second could be used, a rise in absolute pressure of about 50 per cent. per stage could be obtained, so that, in a turbo compressor for 100 lb. gauge delivery pressure, only five to six stages would be required, provided suitable material could be obtained for the revolving disks. Doubtless the metallurgist will succeed ere long in providing the designer with a material which will comply with these conditions; in the meantime the aim is to obtain the maximum overall efficiency with the speeds which are possible at present. To effect this two considerations are of the utmost importance; firstly, the problem of converting the velocity energy of the air as it leaves the impeller into pressure; and, secondly, the problem of cooling the air between successive stages.

As to the first point, it will be obvious that the higher the peripheral speed of the disks, the greater will be the velocity with which the air is projected into the annular space surrounding the impeller, commonly known as the diffuser. Whilst it is possible to convert *pressure* into *velocity* by means of a well-rounded nozzle and with an efficiency approaching unity, the converse unfortunately is much more difficult. The conditions of flow are still imperfectly understood, but the following maxims must be observed if favourable results are to be obtained:—(1) The surfaces over which high velocity air passes must be as smooth as possible; (2) the high velocity air must be correctly guided in all directions to avoid the formation of eddies; (3) the energy conversion must take place along the shortest possible path.

In the earliest forms of turbo compressors, the diffuser was usually bladeless; it was found, however, that the adoption of guide-blades or ribs, now termed "diffuser blades," produced a higher pressure rise and also improved the efficiency. Some makers adopted cast iron blades integral with the casing, but these were difficult to clean up; friction was excessive, and it was almost impossible to obtain the exact inlet angle for all the blades as called for by the designer. To reduce the frictional effect, the spacing of the blades was rather coarse. To obtain accuracy of the inlet angle, diffusers were sometimes cast in rings separately and inserted in the stator. The latter method also allowed of polishing the guide passages, and by employing a non-ferrous alloy, closer pitching of blades and more correct form of guide passage could be obtained.

All cast forms of diffuser blades suffer, however, from the drawback of rough surfaces, which evil can only be mitigated, either by an expensive process of filing and polishing or by providing blades of a smooth material such as sheet brass or sheet steel, the blades being first bent to the desired shape and then inserted in the mould and cast into a suitable ring.

A further improvement in diffuser design has been adopted by the author's firm. The diffuser blades are made of relatively thin strips of highly-polished or planished steel, or bronze, and held in place by distance pieces, which have been carefully shaped and fit into a dovetailed groove in the stator. In this way it is possible to obtain close pitching, a very fine degree of accuracy as far as the desired inlet angle is concerned, and a means of adopting a small entrance angle which in turn renders possible the adoption of the turbo compressor for much smaller volumes than with the older form of diffuser. The diffuser passages are perfectly smooth, thus reducing frictional losses to a minimum; the close pitch of the blades ensures perfect guidance; the shape of the blades provides for a gradual tapering of the passage, and deflects the flow of air from a tangential into a radial direction in a very short distance. Thus the three conditions enumerated above are fulfilled in the best possible manner.

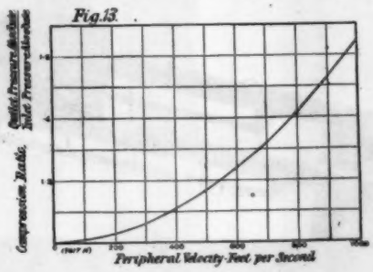
Turning now to the problem of cooling, it will be realised that the greater the pressure rise (that is, the pressure ratio) per stage, the greater will be the temperature rise. In a piston-compressor the temperature at the end of the stroke will be equal to, or less than, that due to adiabatic compression; in the turbo type the maximum temperature is realised at the outlet of the diffuser blades, and generally is above the adiabatic value. This is due to the skin friction between the impeller discs and the casing walls. In consequence, the mean density of the fluid during its passage through the impeller is reduced, and this in turn adversely affects the delivery pressure as well as the energy absorbed at the compressor shaft. For these reasons it becomes imperative to employ the most thorough and efficient methods of cooling.

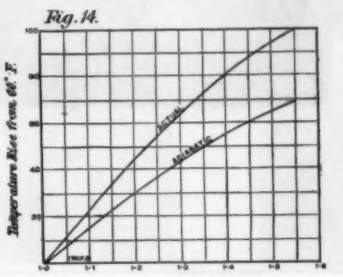
In the early stages of turbo compressor construction it was possible to obtain sufficient cooling effect by water-jacketing the casing. The pressure rise per stage was relatively low, the units were much smaller, and hence the amount of energy absorbed per stage, and which reappeared in the form of heat, could be abstracted with reasonable efficiency by the water-jacketed walls along which the air had to pass from stage to stage. Considering that earlier machines often had 20 or more stages to produce a pressure of 100 lb., the cooling surface obtainable in such a casing was considerable and ample. The modern tendency of increasing the disc speed and thus effecting the total compression in a greatly-reduced number of stages clearly brings about a large temperature rise per stage. This is illustrated in the accompanying curves. Referring to Fig. 13 and taking a peripheral speed of 800 ft. per second, which is now possible, the obtainable pressure ratio is 1·4—that is, an increase of 40 per cent. From Fig. 14 it will be seen that the air under these conditions has a temperature rise of 80 deg. F. per stage.

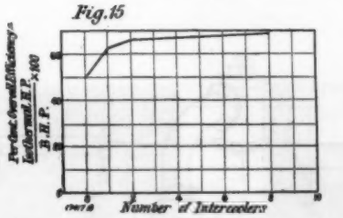
In a unit designed for an output of 10,000 cubic feet of free air per minute, the energy represented by this temperature rise amounts to 350 h.p. per stage, and the equivalent heat energy must be absorbed by the cooling water if the air is to enter the next stage at the original inlet temperature. Obviously it is quite out of the question to provide sufficient cooling area for this purpose in the casing itself, and thus all makers of turbo compressors resort to the use of inter-coolers placed apart from, and usually below, the compressor casing. Considerable divergence in design is noticeable, but in principle the ultimate aim is the same, namely, to reduce the power consumption to a minimum.

Some makers adopt a cooler after every stage; others allow the air to pass through two or three stages before it enters a cooler. The gain resulting from one or more coolers is indicated in the diagram (Fig. 15), which has been drawn for a unit of 10,000 cubic feet of free air per minute, compressed in nine stages to a gauge pressure of 100 lb. per square inch.

The diagram is based on the assumption that after each cooler the temperature of the air has been reduced







to suction conditions. It shows that a marked gain is to be obtained from the adoption of one cooler; a further gain from two coolers, but only a slight further improvement from a cooler after each stage. This further slight gain is negatived in practice by the more tortuous path of the air, so that the best arrangement would appear to be to place a cooler after every third stage—that is, between the third and fourth and again between the sixth and seventh. A cooler after the last stage has no effect upon the power consumption, but is adopted occasionally where cold air is desired.

The compressor casing itself need no longer be jacketed, resulting in a great simplification of this casting; further, all water joints on the casing are avoided. The inter-coolers themselves are of standard design, resembling the condenser of a modern steam turbine installation.

The author hopes that the developments which have taken place in recent years in turbo compressor design will justify the space he has devoted to this part of his subject. He also desires to thank the various firms who have been good enough to supply him with information for the purpose of this paper.

THE PETROLEUM YEAR BOOK.—Persons interested in the various aspects of the petroleum industry will find much useful data and other information in the "Petroleum Year Book," the third edition of which has just been published. The book is divided into sections, of which the first three deal with the production and characteristics of petroleum, and its application to power production and heating. Later sections are devoted to lubricating oils, the oil industry of Great Britain, oil storage and distribution, particulars and records of oil producing companies, statistics and miscellaneous regulations, tables, &c. All the sections have been extended in the current issue, and the section on "Lubricating Oils," which has been written by Mr. Harold Moore, is a new feature; another addition is a section relating to foreign petroleum companies. The price of the book is 10*s.* 6*d.* net, and it is published by the St. James's Press Company, Limited, 15, Henrietta-street, Covent Garden, London, W.C. 2.

NOTICES OF MEETINGS.

THE [ROYAL SOCIETY [OF ARTS.—Friday, June 23, at 4.30 p.m. "Irrigation Enterprise in India," by Mr. F. W. Woods, C.I.E., late Chief Engineer, Irrigation Department, Punjab. The Right Hon. Lord Lamington, G.C.M.G., G.C.I.E., Governor of Bombay, 1903–7, will preside.

THE BRITISH SECTION OF THE SOCIÉTÉ DES INGÉNIEURS CIVILS DE FRANCE.—Monday, June 26, at 5.30 p.m., at the Institution of Mechanical Engineers, Storey's Gate, S.W. 1. A paper will be read by Monsieur A. Antoine, Ingénieur des Ponts et Chaussées, Service de la Navigation du Rhin, on "The Rhine Lateral Canal (Basle to Strasburg)."

THE INSTITUTION OF CIVIL ENGINEERS OF IRELAND.—We have received from this Institution a copy of the 46th volume of its Transactions covering the work of the session from November, 1919, to May, 1920. The volume reprints the presidential address delivered by Mr. P. H. McCarthy, and also a number of papers read and discussed during the session. These include papers on "Irish Bogs," by Mr. T. Tomlinson; "Irish Coal and Coalfields," by Mr. L. J. Kettle; "Irish Water Power," by Mr. G. M. Harrisa, and several others on Irish Transport questions. A list of members is also included in the volume, which is published for the Institution by Mr. John Falconer, 53, Upper Sackville-street, Dublin.

ELECTRIC LOCOMOTIVES FOR PARIS-ORLEANS RAILWAY.—The Paris-Orléans Railway has recently placed an important order for 80 electric locomotives with the Société Oerlikon and the Société de Construction des Batignolles, both in Paris; these locomotives are each for a one-hour rating of 1,720 h.p. The Société Oerlikon is to supply and erect the electrical equipment, while the Société de Construction des Batignolles deals with the mechanical part. The locomotives are specially intended for goods trains, and are to be capable of hauling a load up to 1,200 tons; they are, however, also to be suitable for passenger service, in which case a speed of about 68 miles per hour must be attainable. The locomotives are equipped with four motors wound for 1,500 volts d.c., and having each an output of 430 h.p. measured at the tread.

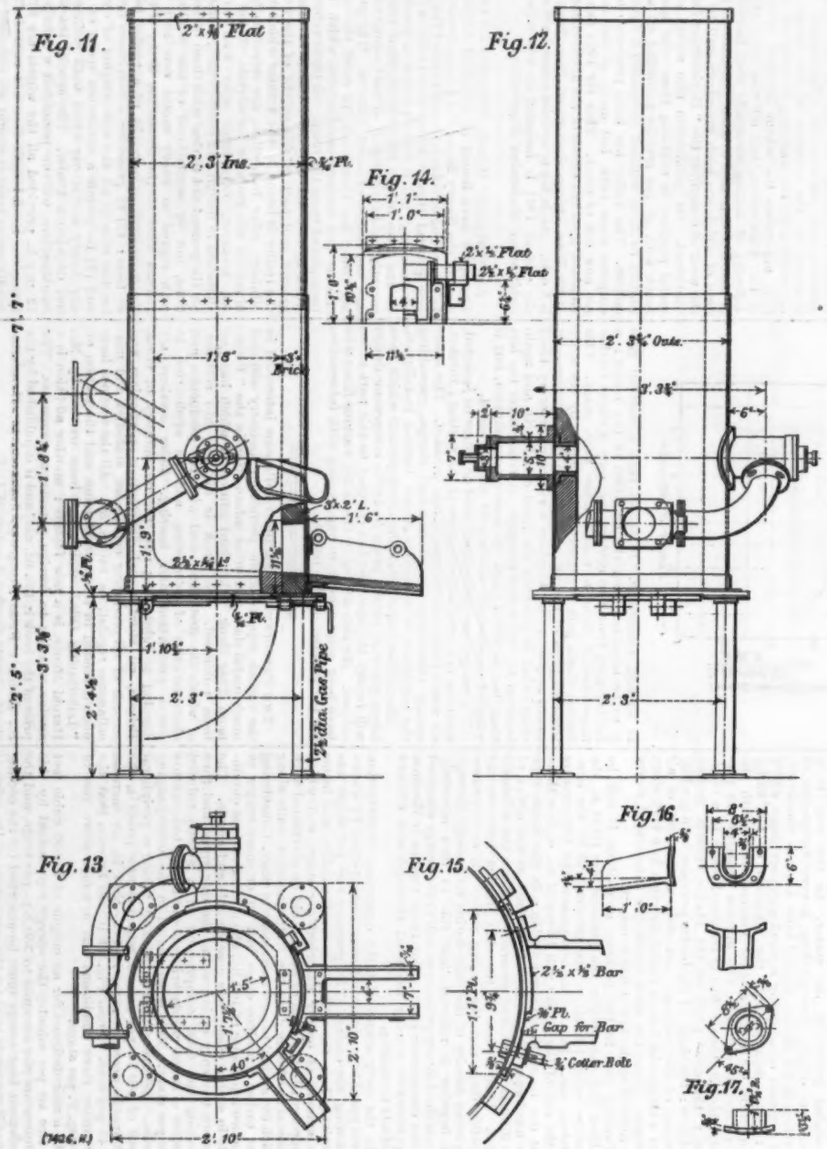
THE ENGINEERING INDEX.—This very useful publication, of which the volume for 1921 has recently come to hand, is now prepared by the American Society of Mechanical Engineers, and the 584 pages it contains include over 14,000 references to articles published in about 600 technical publications, and in some 10 different languages. The subjects are arranged alphabetically, each reference giving the author's name (when mentioned), the name and date of the publication, page numbers and numbers of illustrations, and a brief summary of the contents of the article. Only those experienced in the indexing of technical literature will fully appreciate the labour involved in the production of this publication, but all who have experienced the difficulty of finding an article they have seen or heard of that has appeared in some publication, the name and date of which are both uncertain, will be grateful that the work of compiling the "Engineering Index" is being continued. Its publication also serves an even more useful purpose in enabling those who wish to keep in touch with all the articles published on any particular subject to do so without examining a mass of irrelevant matter. The Index has been prepared under different auspices since 1884, but many of the earlier volumes are now out of print. That for 1921 can, however, be obtained from the offices of the above-mentioned Society at 29, West Thirty-ninth-street, New York, and its price is 6 dols. An index to articles which have appeared since the end of 1921 is included in the society's monthly publication *Mechanical Engineering*.

SIX-WHEELED MOTOR VEHICLES.—The Ministry of Transport have issued to all Local Authorities, &c., a copy of the Heavy Motor Car (Amendment) Order, 1922. In a covering circular letter it is stated that the issue of a new general Heavy Motor Car Order will before long be necessary, but is being postponed pending legislation on the lines of the recommendations contained in the recently published Report of the Committee on Taxation and Regulation of Road Vehicles. The present Amending Order has been made to meet the case of certain tractor and trailer combinations which have recently been placed upon the road. In these vehicles the trailer, when in use, has only two wheels in contact with the ground, and part of the weight of the load carried by the trailer is borne by the tractor which draws it. The Ministry, after inspection, are satisfied that these combinations are suitable for certain classes of transport. As, however, experience may lead to considerable alteration in design and construction, it has been decided for the present not to deal with them by separate regulations, but by amendment of the existing regulations with regard to heavy motor cars and trailers. The general effect of the Amending Order is (1) to increase the permitted axle-weight of a trailer from 4 tons to 6½ tons; (2) to prescribe a maximum limit of 22 tons for the sum of all the axle-weights of car and trailer; and (3) to permit a maximum speed of 12 m.p.h. for any heavy motor car fitted with resilient tyres when not drawing a trailer. The special tractor and trailer combinations will be permitted a maximum speed of 12 m.p.h. provided all the wheels are fitted with soft tyres, the total length does not exceed 33 ft., and the conditions as regards weight are complied with.

CUPOLA AT THE INTERNATIONAL FOUNDRY TRADES EXHIBITION AT BIRMINGHAM.

CONSTRUCTED BY MESSRS. THWAITES BROTHERS, LIMITED, BRADFORD.

(*For Description, see Page* 779.)



FIGS. 11 TO 17. DETAILS OF CUPOLA.

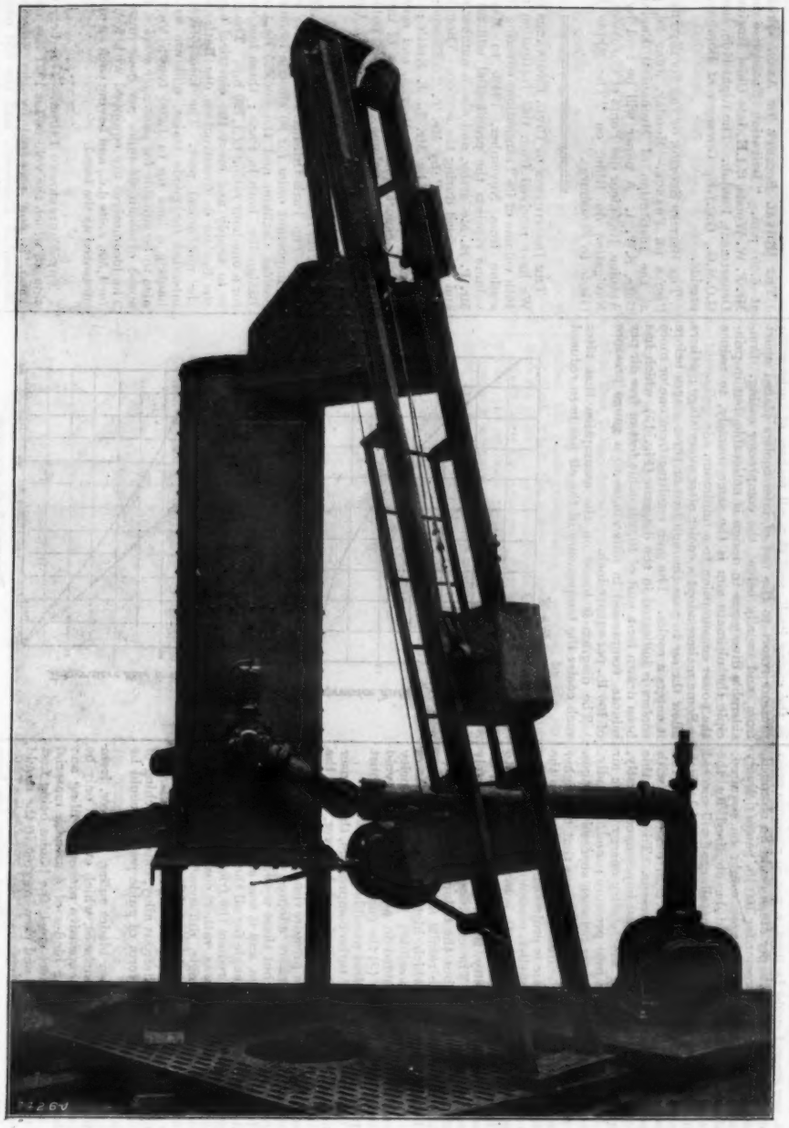


FIG. 18. GENERAL VIEW OF CUPOLA

(To face page 772.)

THE CONSERVATOIRE NATIONAL DES ARTS ET MÉTIERS, PARIS.

(*For Description, see Page* 771.)

FIG. 4. THE INTERIOR OF THE CHURCH OF ST. MARTIN DES CHAMPS.

FIG. 5. THE FAÇADE IN THE RUE ST. MARTIN.

FIG. 6. THE MAIN CENTRAL GALLERY.

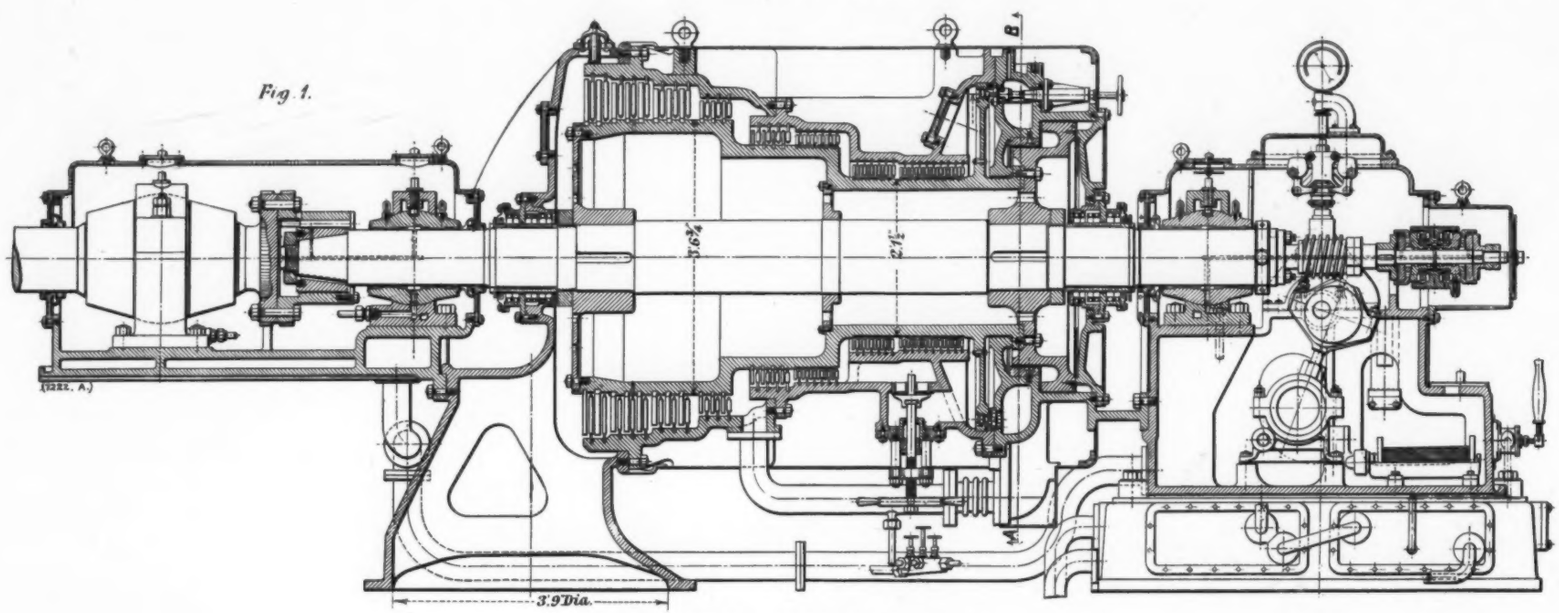
FIG. 7. THE GALLERY OF CLOCKWORK INVENTIONS.

STEAM TURBINES.

CONSTRUCTED BY MESSRS. BELLISS AND MORCOM, LIMITED, ENGINEERS, BIRMINGHAM.

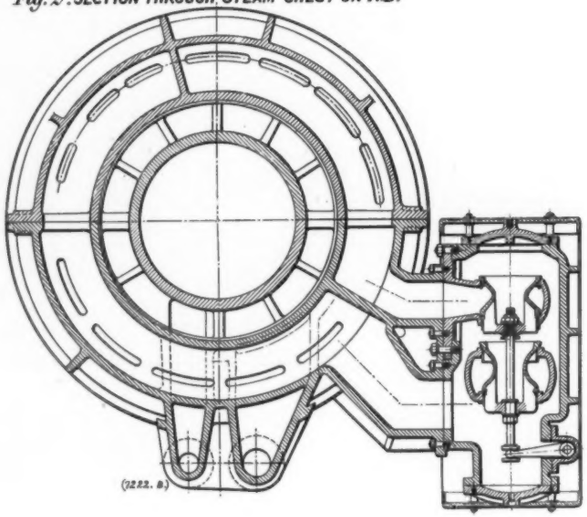
(*For Description, see Page* 773.)

Fig. 1.



AN EARLY 3,000-KW., 1,500 R.P.M., TURBINE.

Fig. 2. SECTION THROUGH STEAM CHEST ON A.B.



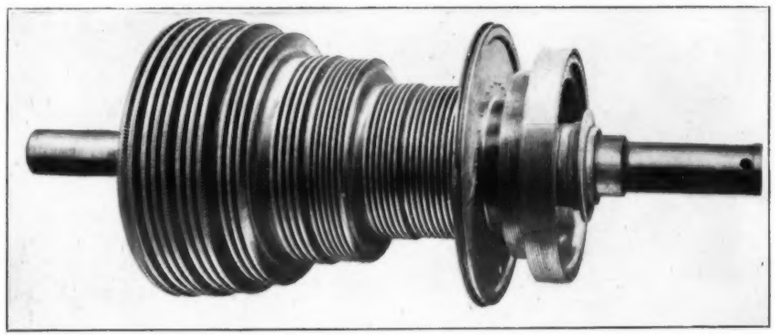


FIG. 3.

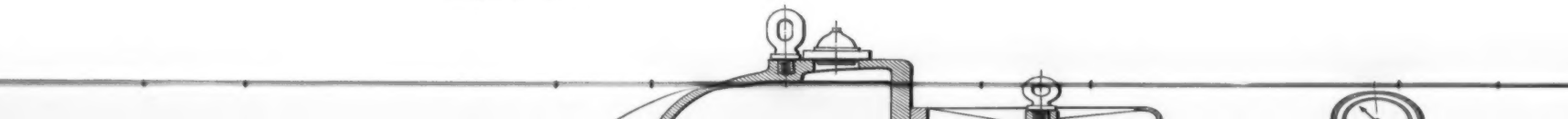
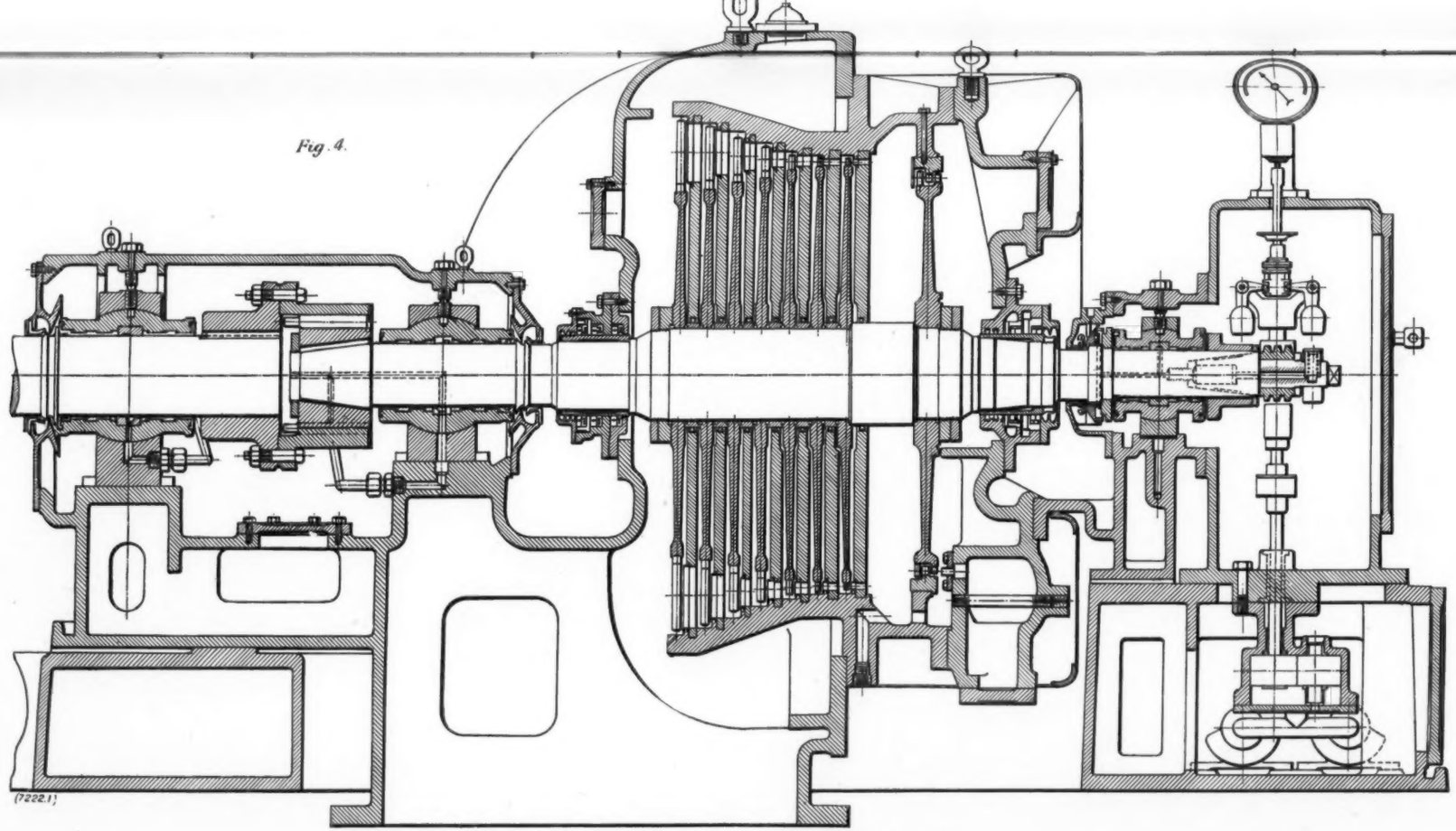
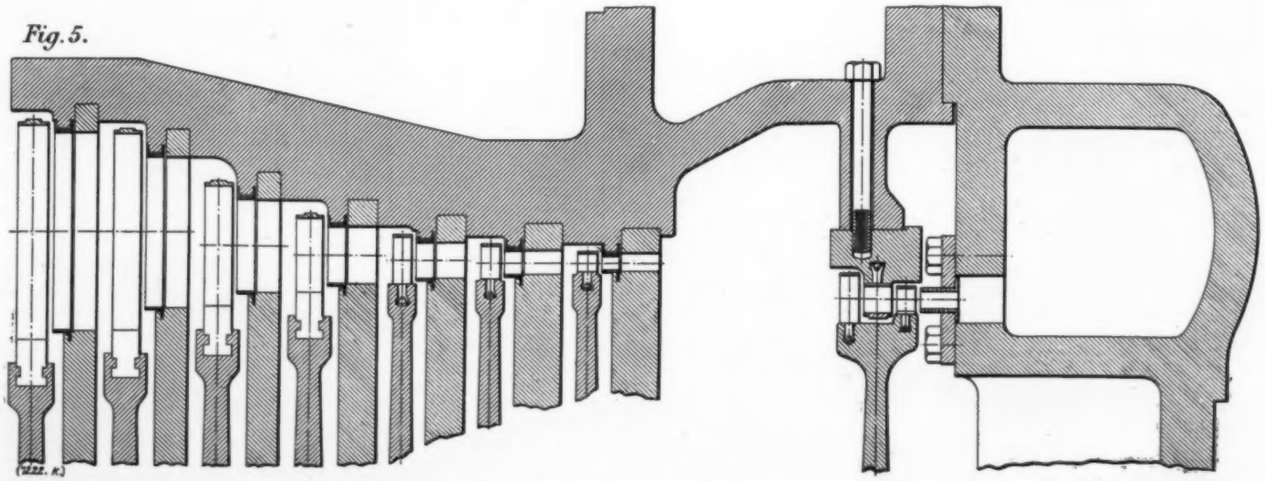


Fig. 4.



A Modern Type of Turbine, 1,000 to 4,000 Kw., 3,000 r.p.m.

Fig. 5.



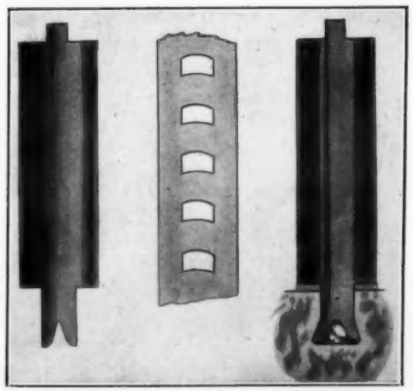


Fig. 6.

15-KW. STEAM TURBINE.

CONSTRUCTED BY MESSRS. BELLISS AND MORCOM, LIMITED, ENGINEERS, BIRMINGHAM.

(For Description, see Page 773.)

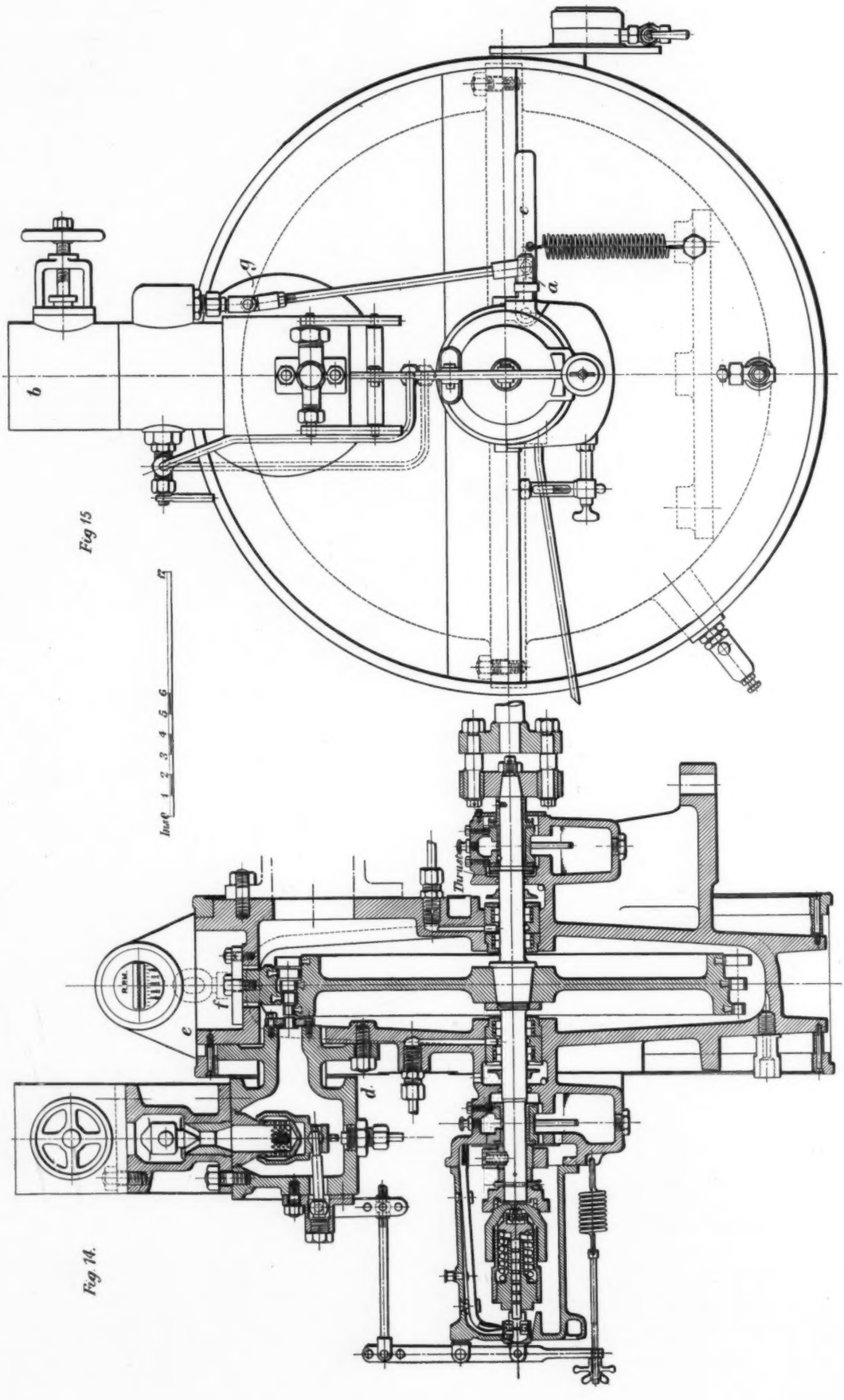


Fig 15

Fig 14.

(To face Page 773.)

ENGINEERING.

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CONTENTS.

	PAGE
The Conservatoire National des Arts et Métiers (*Illus.*)	771
The Belliss and Morcom Steam Turbine (*Illus.*)	773
The Institution of Mechanical Engineers	776
International Foundry Trades Exhibition at Birmingham (*Illus.*)	779
Air Compressors (*Illus.*)	782
Notices of Meetings	785
The Education of the Worker	787
Road-Making Machinery	788
The Institution of Gas Engineers	788
Notes	790
Literature	790
Books Received	792
Industrial Notes	792
Letters to the Editor.—Preheating of Air for Combustion. "The Elastic Limit"	792
Notes from South Yorkshire	793
Notes from Cleveland and the Northern Counties	793
Notes from the South-West	793
The Mechanical Design of Scientific Instruments (*Illus.*)	794
Electric Locomotives (*Illus.*)	795
Catalogues	801
Feed-Water Heaters for Locomotives (*Illus.*)	801

One Two-Page Plate and Two One-Page Plates.—THE CONSERVATOIRE NATIONAL DES ARTS ET MÉTIERS, PARIS (One Plate). STEAM TURBINES (One Two-Page Plate and One One-Page Plate).

ENGINEERING.

FRIDAY, JUNE 23, 1922.

THE EDUCATION OF THE WORKER.

BEFORE the war we were constantly being told how behindhand we were in this country in the matter of education. The Act of 1918 was introduced with a view to improving our position in this direction, but like a good deal of the post-war legislation, has not worked out in quite so practical a way as its promoters seemed to hope. People will always differ, we do not doubt, on the question of education. Idealists would have complete educational facilities forced upon everybody, but in these days of leanness it is essential to give up ideals to some extent and concentrate upon practical propositions. We cannot afford lavish expenditure for only a minute return. Years before the war, girls, suitable in every way for domestic work, became, through the educational system, diverted to other channels of employment. The war, with the attractions it offered to female labour, accentuated the situation.

A similar danger of being educated out of their job would seem to be one of the risks we are in danger of running with regard to our men folk. The Act of 1918, for instance, savoured distinctly of the desire to carry technical education too far. Doubtless some talent would be thus discovered which might otherwise remain dormant, but in the mass we should probably end by making the workers discontented with their lot. If a man's ability is such that he cannot rise above a certain level, more advanced education may only be a disadvantage by making him dissatisfied with his position. It is far more important that the few with special aptitude and characteristics should have the opportunity of being trained and developed along lines which will add to their value, than that every worker at the bench should be able to talk on the theory of the steam engine or cognate topics. For the bulk it will suffice if the facilities given enable them to become highly skilled craftsmen and good citizens, in which latter connection our present educational system has sadly failed in matters such as thrift and industry.

Even if we educated all our men for advanced positions they could not all be foremen, and it is nationally more valuable that we should have intelligent and cheerful workmen rather than a large class who are disappointed. Only in the East can a man cheerfully designate himself as a "Failed" examinee. Besides, numbers of men do not even wish to qualify themselves for more than regular employment as skilled hands. These prefer the freedom from responsibility and the pleasures of some hobby to the more strenuous life and worries which invariably devolve upon those in charge. Most employers have had experience of cases in which skilled workmen have been offered, and have refused, promotion. Clearly for such men, or for youths likely to develop into this type of man, education would more profitably take the direction of good citizenship than advanced technical subjects.

On the other hand, we wish to be to the fore among the nations of the earth, and our factories must be filled with workers of such intelligence that their practical skill and industry is equal to, or in advance of, that common in other countries. For this it is necessary that for all facilities should be available of learning to appreciate the meaning of drawings and fine measurements, conbined with such other practical and elementary theoretical knowledge as will make them skilled at their craft to the highest degree. With facilities for this training, which as a rule exist almost everywhere to-day, it should be possible to select for special attention those who appear to be capable of benefiting by further assistance.

After all we have to realise that education in class-rooms only forms a very small part of a man's equipment for the work of his life. All successful men would readily admit that their education only started at school and had never been completed. Many of the big figures of the world have been men who have educated themselves, either after a school education, or even without one at all. The characteristics which have made for success in these cases are not those commonly developed in class rooms, and generally are not discovered, or indeed discoverable, by a school teacher in boys of immature age.

The foregoing remarks are prompted by speeches made last week at the fourth annual convention of the Association for the Advancement of Education in Industry and Commerce. Sir Archibald Denny, who is president of the association, remarked upon the failure of the scheme for compulsory day continuation classes. Professor Mellanby also dealt with the waste of forcing specialised education upon the large number who could not be, and evinced no ambition to be, other than skilled men. The question is how from the mass to sort out the undeveloped boys upon whom it would probably be worth while lavishing a greater degree of care, with some good chance that they would ultimately prove themselves worthy of this extra attention. That there will always be failures is certain, because many of the characteristics required for the more responsible work can only develop at an age when youths have discontinued instructional classes.

At the conference in question a good deal of attention was paid to the subject of the education of foremen. This was discussed in the light of a report of a sub-committee, presented by Mr. N. J. McLean, of Messrs. Barr and Stroud's works. Now among the characteristics which we hold a would-be foreman cannot acquire except by patient and lengthy work in the shops themselves, is proficiency. It seems to us, instead of giving this due prominence, the report lays far too little stress upon this essential. The leadership of a foreman, we are told, must rest to-day upon the fact that he is a good organiser, with suitable personality, tact, power to handle men, of methodical habits, courage, initiative, able to interpret instructions, and so on. Now these are all very good so far as they go, but though a man possess them all, without proficiency he is nothing. It is not to be expected in these days of high development that a foreman should excel in skill every individual in his shop yet we believe it to be requisite that he should in every sense be fit to be classed as a good craftsman, in order that he may be able to deal effectively with the men under his control and out of whom it is his business to get a fair amount of work. A certain limited degree of deference may be paid to superior education and other points, but the true respect of the shop workers will only be won when the latter are convinced that the foreman really knows his job. The acquisition of the necessary knowledge cannot be secured by any one through continuation classes. A long and practical apprenticeship is the

only road by which to travel to this goal, with, of course, facilities for something more than purely elementary education. In the same way how can a man be trained in courage and initiative by study either at home or in school? It is true that powers of observation, methodical habits, and other desirable qualities may be assisted in their development to a certain degree by class-room work, but the real training ground for foremen remains to-day, in our opinion, the works themselves, and there chiefly, with proper supervision and encouragement, will the right characteristics be developed and built up in the comparatively few suitable men.

ROAD-MAKING MACHINERY.

In all successful manufacturing there must be a proper relation between capital expenditure on tools and the value of the resulting product; and the specialised methods which are in their proper place in the building of a motor car are certainly not, in general, applicable to the building of a house. None the less, a little more of the point of view of the motor car builder would be of advantage to the average public works contractor, or borough surveyor. The application of the methods of the workshop to the type of activity generally classed as civil engineering has made considerable strides in recent years, but the man who has to build a factory or make a road has hardly yet reached the mental attitude of the man who has to build a traction engine.

The modern workshop point of view may briefly be summarised as a realisation of the fact that it doesn't pay to do anything by hand if it can be done by machinery. This aphorism must naturally be used with reason and any number of cases which apparently contradict it could be found without difficulty. None the less, it is a fair brief expression of the truth on which modern manufacturing methods have been built up. As already said, recent years have seen an application of this aphorism to activities of the road-making class, but there is yet very much ground to be covered in this field. That road-making is still looked upon as the activity *par excellence* for the unskilled labourer is sufficiently illustrated by the fact that it is the favoured type of work for those who have to organise relief works for the unemployed. No doubt road-making is a convenient activity on which large bodies of unskilled men can be employed without too glaring a departure from economic methods, but road-making properly carried out no more calls for crowds of men who don't know what they are doing than does sewing machine building.

This appropriation of road-making by organisations dealing with the unemployed has possibly had something to do with the comparatively slow progress of mechanical methods in the art. The fact that so much road-making is carried out by public bodies probably also has a bearing on the matter. Not only is the question of capital expenditure on tools sometimes one of difficulty with a public authority, but such a body is also always diffident about taking any steps which may replace labour by mechanical appliances. This point of view is common, but needless to say is quite unsound. Anything which causes any useful work to be carried out more cheaply is to the public benefit, and even when the main object is to employ the unemployed it is better to employ them as efficiently as possible. This will not only leave more funds in hand for further works and employment, but by increasing the potential wealth of the country will help to decrease unemployment. The more cheaply roads are made, the more roads can the country afford to make.

A further important aspect which should not be neglected when the validity of expenditure on road-making machinery is under discussion is the time saving which such plant may introduce. The delay and attendant expense which the re-making of an important thoroughfare may occasion are difficult, or impossible, to estimate, but in many cases it is certainly very serious, and road machinery by cutting down the time required for repairs or reconstruction would, in many large towns, justify itself on this score alone. In general, however, no such limited justification will be necessary. The plant will more than pay for itself. As an illustration of the use of an appliance in maintenance work which should cut down the time required for repairs, reference may be made to the burning off and drying of patches on sheet asphalt roads which are under repair. This is usually carried out by fire baskets on small wheels, and when the patch is of any considerable area the method is "slow and expensive." This judgment is that of Mr. A. Dryland, the county engineer of Middlesex, who dealt with the matter in a paper presented to the annual general meeting of the Institution of Municipal and County Engineers which is being held at Cardiff this week. Mr. Dryland did not mention it, but an appliance is used for this purpose in America which would appear likely to reduce both the time required for preparation and the time required for drying off. The arrangement consists of a flame from an oil burner which can quickly be started up and can readily be directed over a considerable area.

In his paper, which was entitled "The Mechanical Equipment of a Highways Department," Mr. Dryland surveyed the field of road-making and repair mainly from the point of view of the highway authority. Much of his paper was naturally concerned with the plant which it was desirable such an authority should possess, and the question of the mechanical equipment which should be in the hands of a contractor dealing with a large road-making contract lay somewhat outside his sphere. The ordinary road-making and maintenance which comes within the sphere of the average local authority may, however, be expedited and cheapened by the accumulation of a suitable plant, and Mr. Dryland's paper served a very useful purpose by enumerating and describing the details of such a plant. As an example of the class of work usually dealt with by a contractor, but which Mr. Dryland thought might well be dealt with departmentally, reference may be made to the question of bituminous surface roads already referred to. The patching of such roads requires little else than a portable cooking pot for the preparation of the mastic. Such a plant might well be owned and used by the road authority. Roads of this type are usually laid by contract, in which a maintenance clause is inserted. This practice may be convenient to the borough surveyor, but unless the premises of the contractor are in the immediate neighbourhood of the road it is obviously expensive and wasteful. If a couple of men are to be sent across London to execute a small repair someone will have to pay for the extravagance, and one may be certain that the contractor will cover himself in his original estimate. A reasonable period of maintenance may not be objectionable, but when patching becomes necessary from genuine wear it is clearly best that it should be carried out by the man on the spot.

On the general question of the mechanical equipment of a highways department, Mr. Dryland dealt with the various branches of road-making and maintenance, and described the plant desirable for each class of work. He dealt with his subject under such heads as "tarmacadam plant," "asphalt plant," "tarring plant," "haulage." It is not necessary to follow him into the details of the available machinery under these various heads, as in general it is well-known although not employed as extensively as it might be. Such an obvious appliance as the concrete mixer is by no means always employed in this country, but Mr. Dryland stated that in America it was considered indispensable, "however small the job." Tampers for consolidating trenches and surfaces for concrete roads are also common in America, but as yet little used in this country, although at least one English firm is manufacturing them. For tarmacadam work which has come into use to a greatly increased extent during recent years, Mr. Dryland is inclined to favour the owning of a preparation plant by the authority if it is concerned with roads of any considerable area. The possession of such a plant would enable a road authority to utilise destructor clinker and frequently other cheap local material for light traffic roads and to avoid the purchase of a more expensive article which the conditions to be satisfied may not really call for.

THE INSTITUTION OF GAS ENGINEERS.

The annual general meeting of the Institution of Gas Engineers was held this year in the hall of the Institution of Electrical Engineers, Victoria Embankment, commencing on Tuesday morning last and terminating to-day with a visit to the Beckton works of the Gas Light and Coke Company. The chair was taken at each of the formal meetings by the President, Mr. Thomas Hardie, M.Inst.C.E., and at the first meeting, after the minutes of the previous annual general meeting had been duly confirmed and scrutineers had been appointed for examining the ballot lists for the election of officers and members, Mr. Hardie delivered his presidential address.

Presidential Address.

In this Mr. Hardie first referred to the effects of last year's coal strike, pointing out that the dispute marked the end of Government control and of the artificial conditions which had obtained during the war. It had, however, resulted in the reduction in the price of coal to a level more in accordance with economic requirements, and in this way had proved of incalculable benefit to the industries of the country. Dealing with the general question of the relationship between capital and labour, the president remarked that confidence between capitalists and workers would be to their material advantage and would also benefit the consumer. Co-partnership was advocated as a means of fostering the mutual confidence necessary for successful industrial development. Further reductions in the cost of transporting coal were also mentioned as essential to enable the manufacturing industries to produce cheaper commodities.

Continuing, Mr. Hardie remarked that the question of the quality of coal was of no less importance than its price, and he expressed disappointment that, during the last few months, the improvement in the former had not been more marked. The ash content in certain best gas coals, which was now about 14 per cent., had shown a tendency to rise even before the war. Figures quoted for one gas undertaking were 7·44 per cent. of ash in 1911 and 9·51 per cent. in 1914. The increase, he thought, was in some cases due to the fact that colliery employees did not now carry out their duties with the same assiduity as formerly. Referring to the Gas Regulation Act of 1920, which had been described as "The Charter of Freedom," Mr. Hardie remarked that freedom in this case, as in most others, involved increased responsibility. The quality of gas to be declared as the standard had now to be decided by an officer of the undertaking, and it was not surprising that standards showing little variation from qualities which experience had proved safe in working were generally being declared. He was confident that the system of charging by thermal value, in spite of its slight complexity, was that by which the consumer could best obtain satisfaction.

After brief references to the advantages of water gas plant and low-temperature carbonisation, Mr. Hardie dealt with the use of surplus gas from coke ovens for town supplies, and then went on to consider the new systems of carbonisation involving total gasification. He remarked that these could not be regarded favourably until wages and markets had become more stable, but added that they should be carefully considered for meeting new consumption demands. Some experiences with these systems were related, and the proposal to use oxygen in connection with total gasification was referred to. Other points dealt with in the address were the method of briquetting coal without the use of binding material described by Messrs. Sutcliffe and Evans in a paper before the Chemical Society in April last; the need for refractory materials to withstand higher temperatures; the advantages of chemical control of gas manufacture; the possibilities of effecting economies and increasing efficiencies on other parts of the gas works than the retort house; the importance of employing efficient workmen for investigating faults; and the value of the lighting load. With regard to the outlook for the gas industry, Mr. Hardie remarked, in conclusion, that while concentrated competition from electricity might be expected in the future, those engaged in the gas industry never previously felt

so confident as they did at the present time that their business would continue to flourish.

At the conclusion of the address which was, of course, not open for discussion, a vote of thanks to the President was duly moved, seconded and carried. The next matter for attention was the report of the Council and the accounts for the year ended December 31 last, which the Chairman said had been duly circulated among members. After referring to the losses by deaths of members mentioned in the report, as having occurred during the session and to some which has taken place subsequently, the Chairman proposed the adoption of the report, which was duly seconded. Mr. G. Helps thereupon rose to propose an amendment to the effect that since the report did not deal with the supply of cheap gas to consumers, it should be referred back for further consideration. The amendment, however, was not seconded, and the report was put to the meeting and duly adopted.

The Chairman then called upon Professor J. W. Cobb to make a statement on behalf of the Gas Investigation Committee with reference to the Committee's research on aeration in atmospheric burners. Professor Cobb, after explaining the need for, and scope of, these investigations, said the main difficulty arose on account of the number of factors involved. With a burner in ordinary use so many variables came in that the effect of any one might be obscured or even reversed. The only possible experimental method was, therefore, one which enabled the problem to be dissected into parts. They had first studied the injector action in its simplest form, using a glass jet discharging into a glass tube, and had tried the effects of varying the pressure, density and composition of the gas, the length and inclination of the tube, and other factors. The results obtained had served to dispel the idea that with regard to the performance of burners much could be calculated from formulæ. The two usual theories of injector action in one of which it was assumed that the total momentum of the mixture was the same as that of the gas alone, and in the other that the kinetic energy was the same, had both been proved by the experiments to be untenable even if a constant were introduced. It had been suggested by the American Bureau of Standards that there was a constant ratio between the momentum of the gas jet and that of the air-gas mixture issuing from the burner. This had been found to hold approximately at high velocities, but not at low velocities. The Committee, however, was not yet in a position to summarise the results they had obtained in the form of a report. So far such results were mainly of a negative order. They had, however, obtained some positive results, one of which was that the aeration increased when either the gas pressure or density increased, and whether the experiments were made at equal gas ratio or at equal pressures. They had not yet been able to formulate a general quantitative rule.

The Chairman, at the conclusion of Professor Cobb's statement, remarked that the communication was not suitable for detailed discussion, but he invited any members who wished to do so to ask questions. No questions being asked, he called upon Professor Cobb to introduce the report on carburetted water-gas plant. After Professor Cobb had outlined and explained the work referred to in the report, a brief abstract of which we give below, the work was further summarised by Dr. A. Parker.

Carburetted Water-Gas Plant.

The seventh report of the Research Sub-Committee of the Gas Investigation Committee related mainly to the study of a carburetted water-gas plant with an attached waste-heat boiler. The investigations have been carried out at the Windsor Street Works of the Birmingham Gas Department, with the object of determining the efficiency of the production of carburetted water-gas of a calorific value of about 485 B.Th.U. gross per cubic foot, but since the installation includes waste-heat boilers, data have been obtained showing the amount of steam raised and the resulting increase in thermal efficiency of the whole process. This amounted to an average of 68 per cent., but, if the steam had been raised independently, the efficiency would have been reduced to 59·5 per cent. The efficiency of production of oil-gas, which did not lend itself to accurate determination, during the "cracking" of the enriching oil was approximately 90 per cent., and it is this high efficiency which has brought the efficiency of the whole process up to so high a figure as 68 per cent., although the blue water-gas was produced at an efficiency of only 53 per cent. The overall efficiency of production of carburetted water-gas is thus dependent on the amount of oil-gas mixed with the blue water-gas. The thermal balances of the waste-heat boilers show that the total heat of the steam raised was only 41·9 per cent. of the heat entering the boiler in the first test and only 49·6 per cent. and 43·4 per cent. in two subsequent tests. The amount of steam raised in the first test, however, was sufficient to supply the generators and to drive the blower and auxiliary plant. Trouble has been experienced with waste-heat boilers in some installations owing to leaky joints, but this has not been the case with the plant reported on, owing, it is thought, to the fact that the boilers are allowed to cool for several days before washing out, an operation which was carried out every two or three months. The report illustrates and describes the plant and deals with the method of operating and testing it in considerable detail. The methods of analysing the oil and gases are described in an appendix, and other appendices give the data used in the calculations of efficiency, &c.

At the conclusion of Dr. Parker's remarks, the adoption of the report was moved by the Chairman, who, in doing so, expressed the thanks of the Institution to the Birmingham Gas Department for the facilities granted for carrying out the research, and also invited the discussion. The adoption of report was seconded by Mr. J. P. Leather. A number of speakers took part in the discussion, which followed, but as most of these contented themselves with complimenting the Committee on their work and asking a few questions as to procedure, it is hardly necessary for us to deal with the discussion in full. The questions asked were replied to by Dr. Parker, who also expressed thanks for the interest shown in the work.

The Chairman then announced the result of the ballot for the officers for the ensuing year, and stating that the President-elect was Mr. J. D. Smith, and the Vice-President Mr. James Paterson. Mr. Smith, who was present, expressed his appreciation of the honour conferred upon him, and at this point the meeting was adjourned until the afternoon.

Liberation of Nitrogen and Sulphur from Coal and Coke.

The first item on the programme for the afternoon meeting was the report of the Institution Gas Research Fellowship on the "Liberation of Nitrogen and Sulphur from Coal and Coke," by Dr. A. C. Monkhouse and Professor J. W. Cobb, which is a continuation of that presented at last year's meeting, and referred to on page 562 of our last volume. The Chairman first called upon Professor Cobb to introduce the report, and after Professor Cobb had briefly explained the scope of the work, the results were dealt with in greater detail by Dr. Monkhouse. As far as nitrogen is concerned, the results may be briefly summarised as follows:—The behaviour of the nitrogen in coal and coke has been examined under the influence of heat in an inert atmosphere (nitrogen), in hydrogen, and in steam. Experiments were made with a soft coke (500 deg. Cent.), a medium coke (800 deg. Cent.), and a hard coke (1,100 deg. Cent.). By heating the soft coke in an inert atmosphere, nitrogen was liberated, but up to 800 deg. Cent. only one-third of this nitrogen was obtained as ammonia, the remainder being free. No appreciable quantity of ammonia was obtained above 700 deg. Cent., although above this temperature the coke continued to lose nitrogen. At a temperature of 800 deg. Cent., with the soft coke, an atmosphere of hydrogen, in addition to any preservative action in retarding the dissociation of ammonia once formed, exerted a specific action in liberating a portion of the nitrogen as ammonia, which would otherwise have remained in the coke. By prolonged treatment with hydrogen up to 1,000 deg. Cent. in stages, 68·2 per cent. of the nitrogen of the coke was obtained as ammonia. With the medium coke the attack of hydrogen was feebler and the ammonia recoverable smaller. With the hard coke, the hydrogen had no power of attack up to 1,000 deg. Cent. By gasification of the coke with steam, the whole of the nitrogen was obtained as ammonia, the liberation of ammonia being much more rapid (above 600 deg. Cent.) than with hydrogen.

The following is a summary of the results obtained for sulphur:—The liberation of sulphuretted hydrogen from three cokes prepared in the laboratory at the temperatures above mentioned from Yorkshire bituminous coal has been studied, and it is believed that the nature of the coal used affects the sulphuretted hydrogen results more than the ammonia results, because of the influence of sulphur combined with inorganic elements such as iron and calcium. Of 100 parts of sulphur present in the coal, the percentages occurring in the soft and medium cokes were 56·4 and 50·1 respectively. On heating the cokes in nitrogen, very little sulphuretted hydrogen was evolved up to 1,000 deg. Cent. and very little sulphur was lost from the cokes. On heating the soft coke in hydrogen, sulphuretted hydrogen was evolved steadily up to 800 deg. Cent., when it fell away in quantity. Although the heating in hydrogen was prolonged to 40 hours, sulphuretted hydrogen was still coming off steadily at each temperature when the evolution of ammonia had nearly ceased. At 900 deg. Cent. the evolution of sulphuretted hydrogen increased again in a manner which suggested attack on some compound previously resistant. When the treatment ceased at 1,000 deg. Cent., 93·8 per cent. of the sulphur of the coke had been obtained as sulphuretted hydrogen. No effect corresponding to the dissociation of ammonia was noticed. On heating in steam, the loss of sulphur was rapid, but probably not more rapid than with hydrogen up to 800 deg. Cent. Completion of decomposition could, however, be secured in steam at that temperature when the attack of hydrogen had become negligible.

After moving the adoption of the report, the Chairman invited discussion, and in seconding it, Mr. J. P. Leather enquired if steaming in vertical retorts was likely to produce more sulphuretted hydrogen in the gas. Mr. Smith enquired how, if ammonia was dissociated at 800 deg. C., it could still be evolved at 900 deg. C., and Mr. S. Glover asked for further information as to the quality and size of the coke. To these queries Dr. Monkhouse replied, saying that he thought that more sulphuretted hydrogen would be produced with steaming in vertical retorts, and, with regard to the dissociation of ammonia, pointed out that the time of contact affected the matter. The time of contact in the case referred to was very short, and was insufficient for equilibrium conditions to be established. The size of coke used, he said, was from ¼-in. to ⅛-in. mesh.

The Life of Gas Meters.

The report of the joint committee on the life of gas meters was then introduced by Mr. B. R. Parkinson, who read parts of it in full and omitted others. It was divided into six sections, the first of which gave a *résumé* of the whole question of internal corrosion in relation to modern gas practice. The question was affected by the change from the use of lime to oxide for purification, the latter substance leaving a larger proportion of carbon dioxide and hydrocyanic acid in the gas than the former. A somewhat increased proportion of carbon bisulphide was also allowed to go forward with oxide purification, and this, by interaction with any ammonia present, produced most destructive salts. The principal remedy was the removal of hydrocyanic acid by the chalk process, and, with regard to sulphur compounds, since these were only harmful in the presence of ammonia, attention had to be given to the efficiency of the ammonia washing plant. Corrosive effects were aggravated by the destruction, or "cracking," of hydrocarbons, which otherwise formed natural lubricants and preservatives of the distribution system, and the report pointed out that the absence of rich hydrocarbons in coal-gas could be made up for by the carburetting of water-gas. Aqueous vapour in the gas was given greater freedom of action by the

absence of oily constituents, and might act either as a vehicle for corrosive salts or as a simple aid to corrosion in conjunction with oxygen and carbon dioxide. Paraffin vaporisation is prescribed as a remedy, or palliative, for corrosion and naphthalene troubles, but a gas saturated with water will not hold much paraffin vapour. A table included in the report shows the quantity of aqueous vapour in saturated gas at various temperatures and pressures. Oxygen in the gas has added another corrosive agent. The harmful action of this element on the leathers of the dry meters, the report remarks, is not sufficiently realised. Another section of the report deals with the extraction of hydrocyanic acid by the chalk process invented by Mr. J. G. Taplay, and later sections deal respectively with cases of corrosion investigated during the year, with the effect of vaporising petroleum on the stuffing-boxes of meters, and with the maintenance of pre-payment meters. The remainder of the report is devoted to a memorandum on the new standard sizes of gas meters, a list of which was given in last year's report.

The first speaker in the discussion which followed the reading of this report was Mr. T. Glover, who inquired what was the effect of the corrosive agencies on concrete, and whether it would be possible to use ferro-concrete for lining purifiers. He also mentioned that it was found advantageous to leave a trace of ammonia in the gas in order to assist purification and increase the life of the oxide. The speaker also dealt with the effects of oxygen and remarked that in summer a considerable quantity of water vapour was added to the gas from the water in gas holder tanks. He suggested that analyses of the condensates from meters would be useful.

Dr. Monkhouse, the next speaker, asked on what grounds the statement was made that water vapour in gas affected the question of the addition of paraffin vapour, and Mr. T. Goulden remarked, with regard to the suggestion that oil should be added to the water in gas holder tanks to prevent evaporation, that it was essential that this should be heavy oil, or else considerable trouble might be experienced from the deposition of naphthalene. Mr. S. Glover referred to the importance of the study of the extraction of hydrocyanic acid, and spoke in appreciative terms of the work of the committee in connection with the investigation of the effects of certain added vapours on the packing material in the glands of meters. Another speaker pointed out that the troubles from corrosion were not entirely due to the use of oxide for purification since the change from lime had been made many years ago, while the corrosion troubles had only appeared within the last few years.

Mr. J. G. Taplay, who replied to some of the points raised in the discussion, said he did not think ferro-concrete would be a very suitable material for purifiers but he would make some experiments. He also mentioned that analyses of the condensates from meters had been made and had been found to consist of benzol, naphthalene, creosote and paraffin fractions. With regard to the extraction of hydrocyanic acid by the chalk process, he stated that a plant to deal with 2¼ million cubic feet per 24 hours was now being installed at the Bow Common works. Mr. Parkinson, who also replied to the discussion, said with regard to the effect of water vapour on the addition of paraffin vapour, that the statement was based on some experiments, the results of which were given in an article in the *Gas Journal* some two years ago. He regretted that he was unable at the moment to give the exact reference.

Refractory Materials.

The report of the Refractory Materials Research Committee, which was introduced by Mr. A. E. Broadberry, first referred to the need for improvement of the test for after contraction or expansion as laid down by the Institution's standard specification for refractory materials in November, 1912, as well as for the amendment of the specification itself. The work of revision was well in hand and would soon be completed. With regard to the retort specification, it had originally been contemplated that the retorts would be made only from fireclay with the admixture of "grog," but it was now necessary to add silica and silicious materials, aluminous materials, carborundum, &c., as well as mixtures of any of these substances. Careful attention had been necessary to the clause in which a test piece is required to show no signs of fusion at a given temperature, it having been found difficult to determine what is, and what is not, a sign of fusion. The definition in the notes and appendix to the clause referred to had been found unsatisfactory, and it was now proposed to define signs of fusion as occurring "when the angular edges of the test piece begin to lose their angularity when heated under conditions stated." The contraction test had also proved difficult to carry out in practice, the size specified being too large. It was now proposed to use smaller test pieces and to place them vertically instead of horizontally. An endeavour is being made to overcome the difficulty experienced in taking the necessary measurements by allowing a tolerance of 1 per cent. for experimental errors in such measurements, but the actual allowance for contraction or expansion has been reduced from 1¼ per cent. to 1 per cent. In connection with the standardisation of the after-contraction test, two communications by Miss D. A. Jones, B.Sc., are included in the report, and a valuable paper by Mr. A. T. Green relating to the thermal conductivity of refractory materials at high temperatures is also given. These communications, especially that last mentioned, do not readily lend themselves to abstracting, and we regret that the demands upon our space preclude the possibility of our giving them in full at the present time.

A brief discussion followed the reading of this report, the first speaker, Dr. Harker, calling attention to the importance of testing refractory materials under loads. Professor Cobb disagreed from the definition of fusion suggested in the report, and recommended that it should be defined in terms of the possibility of a particular Seger cone. He also referred to the effects of porosity on heat transmission. Mr. J. P. Leather said he had carried out some experiments on conductivity similar to those described in the report, but had used the calorimetric method which he thought was preferable to that employed by Mr. Green. In reply to Professor Cobb, Mr. T. F. E. Rhead said he did not think there was much advantage in the definition of fusibility which Professor Cobb had suggested. In a Seger cone, he said, the tip bent down and touched the base, and the speaker asked if the test piece should behave in the same manner. The test piece would have to be accurately ground to the same dimensions as the cone, and there would be considerable difficulty in grinding some specimens. In some cases, the speaker added, difficulty would arise from the fact that while the material kept its shape the matrix fused and ran out. Mr. Broadberry, who was then invited by the chairman to reply, said he had nothing to say except to thank the speakers for the useful remarks they had made. The meeting was then adjourned.

(To be continued.)

NOTES.

Aeronautical Research.

In order firmly to establish the custom of drawing the material for the annual Wilbur-Wright Memorial Lectures alternately from British and American sources, it was the intention of the Council of the Royal Aeronautical Society to invite an American to prepare the lecture this year. The arrangements made, however, did not materialise and the lecture was therefore delivered on the 15th inst. by Mr. A. Ogilvie. The lecturer, who, from a long and intimate personal connection with the Wright brothers was able to speak with authority, first showed that their early work with gliders and power-driven machines was successful only because the machines were designed on a scientific basis founded on definite data obtained by experimental research work in the wind channel. The reason, the lecturer remarked, that these research data were not made public was that the financial situation of the Wright brothers and their obligations to the purchasers of their patents, compelled them to keep them in their own possession. Evidence of its general adequacy was, however, given by comparing the design of a small racing machine, produced in 1910 to compete for the Gordon-Bennett Cup, with that of the standard machine of the same period. In both machines, the aspect ratio was about 6 to 1 and the gap-chord ratio about 1, both of which proportions are still standard practice. The wing loading, however, was increased from 2¾ lb. to 6 lb. per square foot, a step which could hardly have been taken but for the possession of trustworthy aerodynamic data. The lesson to be learnt from the success of the Wright brothers, the lecturer continued, was that the whole basis of aeronautical progress depended upon laboratory research and he proceeded to consider the past, present and future position of research work in this country. Between 1909 and 1914, he pointed out, aeronautical research, both at the National Physical Laboratory and at Farnborough, as well as by independent experimenters, had provided a very large amount of the necessary fundamental data from model experiments, and practically all the vital features of the information had been checked by full-scale work. During the war, although progress in the art of flying was rapid and continuous, as also were the developments in methods of construction and design from an engineering standpoint, there was, in the lecturer's opinion, no substantial progress in aerodynamics. Since the war, he said, research had steadily dwindled until it was now at a lower level than in the pre-war period, when a large amount of work was being carried out by private firms and individuals in addition to that done at the state-supported establishments. The importance of fundamental research was not grasped by the authorities in this country, the lecturer remarked in conclusion, but such research was essential if the world at large was to reap the full benefit of the achievements of Wilbur Wright and his brother.

The Railways and Road Transport.

The great waste of time and money occasioned by the manner in which the Ministry of Transport opposed the Railways (North-Western and Midland Group) Bill in Committee last week, at the eleventh hour, has been the subject of universal comment. When it is remembered that in such a case it is necessary for a large number of experts on all sides to be in attendance, in order quickly to furnish data which may often prove decisive one way or the other, and that the Committee sat for ten days before any sign of opposition was made by the Ministry, it will be evident that this waste of time and money has been very great indeed. It is a great pity that the Ministry could not have stated its criticism earlier so that the negotiations between the railways and the traders, on which the fabric of the whole Bill was reared, could have been conducted in the knowledge of the Ministry's views. It is well known that the Bill was withdrawn simply because the promoters considered that working along the lines suggested by the Ministry would have been breaking faith with the parties with whom they had come to agreement, and that it was impossible to proceed on those lines without fresh negotiations with the traders. The matter will, of course, not rest where it is at present, and we are glad to see in a special report issued by the Committee which considered the Bill, not only strong criticism of the delayed action of the Ministry, but also the opinion expressed that, "Subject to eliminating unfair competition, the Committee were unanimously of the opinion that it would be in the public interest to allow the fullest possible participation by the railway companies of this group and all competitors in the service of road transport."

LITERATURE.

The Emission of Electricity from Hot Bodies. By O. W. Richardson, F.R.S., Wheatstone Professor of Physics, King's College, London. Second edition. London: Longmans, Green and Co. 1921. [Price 16s. net.]

This work, one of the monographs on Physics published under the editorship of Sir J. J. Thomson and Professor Horton, made its appearance in 1916, and to judge from the author's revised and extended edition very little work on the subject of thermionic emission has been attempted since. The number of references to original papers prior to that date is very large, and attests the care with which the

literature was searched in tracing the progress of the inquiry. The references to the experiments and deductions of the last five years are very brief and scanty. This is the more surprising as a sufficient stimulus to further research is apparently provided by the extent to which industrial progress, in certain important directions, would be benefited by the application of the theory of the emission of electricity from hot bodies. The rectification of alternating currents and the magnification of small currents in radiotelegraphy and radiotelephony are two directions, in which thermionic emission has found practical application, and to which much experimental work has necessarily been applied. The list of works referred to by the author, in his earlier preface, as providing an adequate substitute for the omitted technical matter, has not been enlarged by including more modern works.

It has long been known that air in the neighbourhood of hot surfaces has the power of conducting electricity, but little progress could be made in penetrating the true character of the phenomena till the end of the last century, when Sir J. J. Thomson established the electron theory and proved that the negative ions emitted from a hot carbon filament at a low pressure were electrons. The conductivity of metals could then be explained, as arising from the behaviour of an atmosphere of electrons, which under ordinary conditions were in violent and irregular motion like the molecules of a gas. But under the influence of an electric field, these electrons assume a definite average velocity in the direction of the electric potential gradient, constituting the electric current. It is further easily conceivable—perhaps too easy—that with rising temperature the energy of these electrons would be increased, and that if the temperature be made sufficiently high a point would be reached at which the energy would be great enough to carry them through the surface of the hot body. In this view, the escape of electrons from a heated metal, or salt, can be regarded as analogous to that of molecules of a vapour from a liquid during evaporation. This explanation seems sufficiently simple to win general assent, though some may ask whence the escaping electrons acquire their energy, and others fail to see its application to the phenomenon of liberated positive ions under similar circumstances. The first objection remains unanswered though plausible suggestions may be made. It is difficult to see that experiment can render any assistance here, but to remove the second, Professor Richardson devotes no inconsiderable portion of his book, and in so doing goes far towards settling a long-standing controversy.

When the electron was unknown and the origin of the electric current unexplained, it was natural to regard the phenomena that electric emission exhibits, as due to obscure chemical action arising from the heated metal in connection with the surrounding gas, or to impurities in the metal itself. Such a view denies the sufficiency of thermal energy to supply the source, and probably there are not wanting those who maintain this view. But the evidence that is accumulating must reduce the body of adherents, and the author, who stoutly upheld in 1916 that true electronic emission could be produced from the metal itself, physical in its origin and reversible in its operation, has had no reason to modify his views. The experimental evidence on which this conclusion rests is fully and fairly set out, the results that tell for the physical as well as those that favour the chemical hypothesis are both fully discussed. Especially has the emission from carbon been held to be due to the presence of gas contaminations. The experiments that support this contention are described and criticised with care, and the conclusion of the author after taking all the facts into consideration is "that they afford no support to the theory that the emission from carbon can be explained by chemical action. It may be that such a chemical effect exists, but its existence is not demonstrable, or even rendered probable by the evidence which has been submitted." The alkali metals are also quoted as a source of electron emission from chemical action, and the evidence is perhaps slightly stronger than in the case of carbon. The greater heat liberation per gramme equivalent shows that the reactions are much more vigorous than in the case of the refractory elements usually selected for experiment, and therefore some emission effects might be expected, but even in this favourable instance convincing proof is wanting.

The evidence on the physical side is of quite a different character. The author's experiments on tungsten afford a very positive confirmation of the efficiency of thermal origin. In this case, the precautions against possible contaminants were exceedingly stringent. The filament was heated to a temperature of over 2,200 deg. C., and the exhaustion of the bulbs was continued for many hours, till the evolution of gas was very small and practically constant. The contention is, that nothing but pure tungsten could remain after the severe treatment to which the filament had been subjected. Yet this tungsten filament was able to continue the emission of electrons indefinitely. This test seems fairly conclusive, especially when taken in connection with Langmuir's experiments that prove that the presence of ordinary gases have the effect of diminishing the extent of the emission.

Another problem narrowly connected with the fundamental phenomena of thermionic emission is that of photo-electric action. When ultraviolet light falls on clean metals an emission of electrons is the consequence. Here the emission is due to the action of an external source, but inasmuch as all substances emit light when at a sufficiently high temperature, it might be argued that as the radiation contains every wave-length without limitation, the emission of electrons from an incandescent body may be an effect of its own luminosity, called by the author an auto photo-electric emission. It is of the utmost importance to settle this point, but unfortunately as in the extent of chemical action, it is impossible to produce experimental evidence of an irrefragable character. The auto-photo-electric emission varies as the temperature of the incandescent body is raised in the same way that thermionic emission varies. Qualitatively no decision can be reached, and the quantitative values, derived experimentally, involve such extraordinary difficulties that the results are accompanied by much uncertainty. The only method that can give decisive evidence "is to find whether the values of the auto-photoelectric current at a given temperature, as calculated from photoelectric data, agree with the observed thermionic current at that temperature. The main conclusion, that the auto-photoelectric currents are too small in amount to account for the measured thermionic emission, seems warranted. This was the decision in 1915, and apparently the experiments of the last six years confirm this conclusion, but it is characterised by the same hesitation and the question is still *sub judice*. This conveys no censure on the methods of physicists, the problem is probably insoluble, on the one hand on account of the experimental difficulties in determining the correct values of either the photoelectric or the thermionic currents under given conditions, and on the other by reason of the serious mathematical difficulties attending the rigorous treatment of the theoretical problems involved.

Another controversy, which remains unsettled, or one in which the evidence fails to command universal consent, is the nature of the origin of the contact potential difference observed between two different metals, whether it be chemical or electrical. The experiments in connection with thermionic emission are not only able to throw some light on this vexed question, either side of which may claim the support of eminent authorities, but may eventually give this long-protracted dispute its quietus. The connection between Volta's contention, of more than a century ago, "that the metals can of their own virtue excite and dislodge the electric fluid from its state of rest" and the behaviour of the thermionic emission, is too subtle to be elaborated here, and it would be premature to insist upon any conclusion as definitive. But the pursuit of the main topic into some unexpected byways adds a great charm to the book, illustrating both the delicacy of experiment and the acuteness of exposition.

The emission of positive ions has hardly been submitted to the same severity of experiment as have electrons, but where the currents have been measured with the accuracy obtainable as in those by Strutt on Copper and Silver, in both air and in hydrogen, the currents observed can be represented by the same formula as that which governs the negative emission with change of temperature. In fact, one exponential formula, containing two constants, governs all cases of emission of both positive and negative ions from solids in which the emission can be regarded as a definite function of temperature. To what extent the presence of gases or impurities is necessary to produce the positive ions that carry the initial emission from hot bodies, it may be premature to decide, but the author reviews the main points that favour a gaseous origin of the ions in question, and finds none of them incompatible with the view that he strenuously supports, namely, "that the initial positive ionization from hot metals consists of charged atoms of the alkali metals, and chiefly of atoms of potassium." This conclusion is unexpected, and for its acceptance the author relies not a little on his own ingeniously contrived experiments for determining the electric atomic weight of the ions. The results of these experiments give a definite answer, if they are sufficiently accurate and refer to the ions under discussion. The accuracy seems more than sufficient, but the second condition must be left to the decision of experts. But it may be added in conclusion that here as elsewhere, throughout the book, the description and critical examination of the many experiments that have been devised constitute a main and valuable feature, supplying new grounds for the study of an inquiry of remarkable interest and a further incentive to its pursuit.

The Airplane Engine. By LIONEL S. MARKS, B.Sc., M.M.E. First edition. New York and London: McGraw-Hill Book Company, Inc. [Price 30*s.* net.]

FEW, if any, branches of technical activity have had applied to their development the same intense study and keen incentive towards progress as the machinery for propelling aeroplanes. In every direction the conditions arising out of the great war were unique. As a weapon of decisive moment in its influence on the waging of warfare the aeroplane proved to have an ever-increasing and compelling importance, and in the progress of the machine as a whole the engine was, and is, the prime factor. Researches, investigations and trials of quite unprecedented scope and in countless numbers were incessantly pursued. The war-time work, moreover, could not be kept secret, because of the continual exchange of machines by capture, so that all the belligerents were aware, within a relatively short period of time, of any successful innovation put into practice, by any one of the others. Engines captured were immediately and minutely examined for any potentialities that might be disclosed, and during the last few years the results of these examinations have been made public and have revealed the remarkable thoroughness with which they were conducted, and have presented a mass of data, equal in scope and completeness to any existant to-day, even in connection with prime movers of many times the age. Owing to the world's determination to maintain peace, and to the financial stringency arising out of the war, the aeroplane is not likely to be subject to any very great immediate improvements, yet as against the return of normal times, sure again to foster steady development, a text-book on this subject, bringing information up to date, is to be welcomed.

The volume under review is to be commended in giving first of all, briefly, the theory of determining the horse-power required for flight under various conditions and also the equating of the propeller to the variables. Secondly, the broad principles of internal combustion are only shortly treated in a general way, and are elucidated by particular references to aeroplane engine practice and performance. Particularly thorough is the treatment of inertia forces, balance and the theory of off-setting the cylinder centres in regard to the crank centres. The next section of this volume draws from the very complete drawings and particulars that are now available, as already mentioned, of the leading aero engines of the day—the Napier "Lion," Rolls-Royce, Maybach, Benz,

Fiat, Hispano-Suiza, Liberty and one or two other American engines. Similarly, engine materials are fully dealt with, complete tables being given. Engine details are amply explained and illustrated. The principal radial and rotary engines, the Gnome, Le Rhone, B.R. 2, Clerget, Siemens-Halske, A.B.C., Dragonfly, Salmson, are illustrated. Subsequent chapters deal with fuels, the carburettor, fuel systems, ignition, lubrication, the cooling system, geared propeller drives, supercharging manifolds, mufflers and starting, all with definite reference to aeroplane requirements. Throughout the volume, the illustrated drawings and tables, diagrams, and curves are very clearly reproduced to an ample scale, and as an indication of the fullness of the illustrations, it may be stated that there are 341 figures. The subject has been treated all along in accordance with aero-engine requirements, and a study of the many data reproduced shows clearly that this science is a separate and a complete one.

The lessons to be learnt here are certainly applicable to other spheres, but only in a very much less degree than was earlier expected. With automobile work the conditions are so different that the internal-combustion engine problems there must be approached from an entirely different angle. Mr. Marks's book, as was only perhaps to be expected, is more complete from the American and less from the British standpoint, than we could desire. The subjects of air cooling the cylinders and supercharging, for instance, are worthy of more detailed attention than they have been given. In regard to air cooling in particular, the amount of work done in Britain and the extremely good results obtained are one of the definite land marks in internal-combustion engine progress. The final chapters dealing with potential developments does not hold out much hope of any probable radical change in the near future. The adoption of the same method of injecting the fuel as with the Diesel engine, *i.e.*, at the end of the compression stroke, would overcome some of the difficulties of limited compression or detonation. The author holds out hope for this method of injection in conjunction with the Junkers two-stroke cycle, opposed-piston engine, each horizontal piston driving separate cranks coupled together and to the propeller by gearing. Modifications of the Otto-cycle, as in the Zeitlin engine, the general development of the two-stroke cycle engine, the adoption of steam or the Diesel engine for aero work, compounding with internal-combustion machinery and the gas turbine, are still very much in the future.

BOOKS RECEIVED.

The Lead Storage Battery. By H. G. BROWN, A.M.I.E.E. London: The Locomotive Publishing Company. [Price 5*s.* net.]

Metallography. By CECIL H. DESCH, D.Sc., Ph.D. Third edition. London: Longmans, Green and Co. [Price 16*s.* net.]

Alternating Current Electrical Engineering. By PHILIP KEMP, M.Sc., M.I.E.E. Second edition. London: Macmillan and Co., Limited. [Price 17*s.* net.]

United States Geological Survey. Professional Paper No. 129—C. *Graphic and Mechanical Computation of Thickness of Strata and Distance to a Stratum.* By J. B. MERTIE, Junior. No. 129—E. *The Byram Calcareous Marl of Mississippi and its Foraminifera.* Papers by C. WYTHE COCKE and JOSEPH A. CUSHMAN. Washington: Government Printing Office.

Electric Ship Propulsion. By Commander S. M. ROBINSON, R.S.N. New York and London: Simmons-Boardman Publishing Company.

Aviation in Peace and War. By Major-General Sir F. H. Sykes, G.B.E., K.C.B., C.M.G. London: Edward Arnold. [Price 8*s.* 6*d.* net.]

Some Things That Matter. By Lord RIDDELL. London: Hodder and Stoughton, Limited. [Price 7*s.* 6*d.* net.]

Transactions of the Liverpool Engineering Society. Vol. XLII, 1921. Edited by Assoc. Professor T. R. WILTON, M.A., M.Inst.C.E., M.Cons.E. Liverpool: Offices of the Society.

Wireless Telegraphy and Telephony and How to Make the Apparatus. By E. REDPATH. London: Cassell and Co., Limited. [Price 1*s.* 6*d.* net.]

Notes Économiques d'un Metallurgiste. Par CAMILLE CAVALLIER. Paris: Gauthier-Villars et Cie.

Steam Power Plant Auxiliaries and Accessories. By TERRELL CROFT. First edition. New York and London: McGraw-Hill Book Company, Inc. [Price 15*s.* net.]

Insulating Varnishes in Electrotechnics. A Text Book for Electrical Engineers and Students. By ALFRED R. MATTHIS. Manchester and London: John Heywood, Limited. [Price 7*s.* 6*d.* net.]

The "Electrician" Annual Tables of Electricity Undertakings, 1922. London: Benn Brothers, Limited. [Price 10*s.* net.]

INDUSTRIAL NOTES.

THE output of coal declined steadily during the four weeks ending June 3. In the last week of that period it amounted to 4,440,900 tons, against 4,945,200 tons in the week ending May 13, while for the week ending April 29 the output was 5,160,100 tons, which was the highest amount produced in any week in the year ending June 3, 1922.

In May the Board of Trade index numbers for wholesale prices for foods showed a small increase of 0·1, while for materials the increase compared with April was 0·7. For all articles the increase worked out at 0·5. The index figure for May for all foods was 171·6, and for all articles 164·0.

The two important events of the past week have been the settlement of questions outstanding between the boilermakers, foundrymen and employers, and the return to work of the members of the Amalgamated Engineering Union.

In connection with the former an official statement has been issued to the effect that the National Union of Foundry Workers and the Engineering and National Employers' Federation conferred together on the 14th, 15th and 16th of this month, and arrived at joint recommendations regarding overtime, night shift and payment by results, and these would be submitted to the constituent bodies of both sides for early ratification.

The Boilermakers and Iron and Steel Shipbuilders have also during the week accepted the terms of the agreement between the Employers' Federation and the trades unions. This virtually completes the settlement of the recent dispute.

After so protracted a stoppage it is of course natural that large works can only recommence by degrees. The result has caused a little disappointment among the men who, for the most part, seem to have been quite anxious to return to work. In some works practically all the men are back, but in others the nature of the work has necessitated starting some before the whole staff could be found employment. It is satisfactory to note that, now that there appears to be a prospect of something being done, orders are beginning to come in. It is reported that work is to be resumed on some of the Cunard liners; orders have been placed in Sheffield for railway material, while orders for gates for the new dock at Swansea are reported to have been placed with Messrs. Armstrong, Whitworth.

Official returns analysed lately in the *Daily Dispatch* show that important trades unions have lost no less than 22 per cent. of their members during the past year. The depletion of the union funds has also undoubtedly been enormous. The whole year has been a disastrous one to the trade union movement. There appear, however, to be indications that the bulk of the men are becoming tired of the policy of the extremists, and are beginning to realise that they are not quite so able as leaders as they have been taken to be. Certainly the financial and other results of the past year are not greatly to their credit. It is to be hoped that now that settlement has been arrived at in the most important industries we shall be allowed a sufficient period of peace to get the trade of the country on its feet again and to enable the large amount of unemployment to be considerably reduced.

The drop in the bank rate to 3½ per cent. announced last week is expected to stimulate trade revival. Cheap money is essential to industry, and the reduction is opportune.

A conference had been arranged for Wednesday last between the engineering unions and the Engineering Employers' Federation to discuss the question of the reduction of the war bonus, but has been indefinitely postponed.

A joint meeting of the National Transport Workers' Federation and the port employers has been held to consider the various questions including reductions in wages. The Workers' Federation has intimated to the employers that they cannot, in view of the short time at present worked, agree to further reductions, except in connection with the clerical and permanent staffs. They also proposed that both sides should endeavour to co-operate in working out a scheme of labour maintenance and adjusting anomalies without affecting present basic rates. At the time of going to press negotiations are still proceeding.

At the Annual meeting of the Soldiers' and Sailors' Help Society it was stated that the number of disabled men dealt with in the workshops in the year had been 2,301, of whom many had been passed on to outside employment. Sir Harry Greer, M.P., states that the Society had had a dispute with the Woodworkers' Union, the latter having objected to the Society taking contract work because its men were not members of the Union. This attitude of hostility to any work intended to help the disabled who have suffered in the service of their country has been a remarkable feature of trade unionism since the war, and is as regrettable as it is astonishing.

PREHEATING OF AIR FOR COMBUSTION.

TO THE EDITOR OF ENGINEERING.

SIR,—We note in the report, in your issue of June 2, of Mr. Mitchell's paper, read at the Glasgow summer meeting of the Institution of Electrical Engineers on May 30, that the author, when commenting upon boiler efficiency figures obtained from the plant at Dalmarnock Station, states that "the chief source of loss is in the heat escaping in the flue gases" and that the preheating of the furnace air supply would improve the efficiency.

It is common knowledge that at sea very considerable saving has been effected by this means, and we believe that there is a growing opinion that similar economies can be obtained for land installations. The saving is not limited to the mere recovery of heat, which, otherwise, would be wasted.

The conditions in the furnace are greatly improved. The temperature of the combustible gases and volatile vapours arising from the fuel on the grate is not reduced below ignition point and, with forced draught, these gases are mixed much more thoroughly with the air than with natural draught, giving a homogeneous and readily ignitible mixture. There is consequently less risk of a portion of the gases escaping unburnt, and the amount of excess air can be much reduced. All these factors tend towards improved efficiency, quite apart from heat recovery.

It should be recognised that the economical performance of a boiler is the product of two efficiencies: The ratio of the heat produced to the calorific value of the fuel, which depends upon furnace design and conditions, and the efficiency of the transference of that heat to the water, which depends upon boiler design. It seems logical therefore, that combustion, the fundamental process in steam raising, should be perfected as far as may be possible and, for this reason, we believe that the preheating of the air should have the first claim upon the heat in the waste gases. In any case we thoroughly agree with Mr. Mitchell's conclusions.

We are, yours faithfully,

For JAMES HOWDEN AND CO., LIMITED,
CRAWFORD W. HUME, Director.

195, Scotland-street, Glasgow, June 15, 1922.

"THE ELASTIC LIMIT."

TO THE EDITOR OF ENGINEERING.

SIR,—*Apropos* of the correspondence that is taking place in your valuable paper re "Fatigue of Material and the Relative Values of Elastic Limit and Breaking Strain," kindly allow me the necessary space to point out, that in 1887, before the North-East Coast Institution of Engineers and Shipbuilders, a paper was read in which the following passage occurs:—

"Suppose a bar of steel or other material having a tensile elastic limit of 15 tons per square inch and a maximum strength of 30 tons to be placed in the testing machine and a tensile strain applied; then so long as the elastic limit of 15 tons per square inch was not exceeded, the elongation of the bar would be directly proportional to the load applied; if, however, the elastic limit was exceeded the bar would take a "set" and would continue to do so as the load was increased. After reaching 20 tons per square inch suppose all strain to be removed and the experiment commenced over again, it would now be found that the elongation was proportional to the load applied, up to, or nearly up to, the point where the experiment had been previously discontinued; in other words, the elastic limit would be pushed up from 15 tons to 20 tons, and any one afterwards testing the bar, and being ignorant of its previous treatment, would register its elastic limit as 20 tons per square inch. In the same way the elastic limit of the bar could be gradually increased until it nearly coincided with the maximum strength, and the elasticity of the bar would be perfect, from zero, nearly up to its breaking strain. To assume therefore that when the first elastic limit was exceeded, the bar was no longer elastic was quite erroneous, for probably in more than 999 springs out of every 1,000 manufactured, the first elastic limit was thus lifted up, and advantage taken of the increased elastic strength thereby induced."

The above truth was established by experiments, conducted over a number of years, prior to its publication, and as you will notice by the date, it was established in the age of older men. It still holds good, however, in this age of younger men; only, judging from the correspondence, they have not yet devoted sufficient time to the study of the subject to make themselves conversant with facts that were established in the good old days. Generally speaking, that seems to be just what is wrong with this old world to-day.

Surely it has been established long enough, that if destruction is required, then give the job to the youngsters They never recognise anything but breaking strain.

If, on the other hand, construction is required, then listen to what the older ones have to say. They consider elastic limit first, not only with regard to materials, but most other things. Experience is the only teacher that is never underpaid.

Yours faithfully,

"CONVINCED."

Sheffield, June 17, 1922.

NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

Iron and Steel.—With the return of expert craftsmen, more hopeful conditions have been restored in the engineering section. Some thousands of semi-skilled and labouring operatives have been taken on to deal with arrears of orders and new business. The proportion of foreign contracts materialising for machinery and implements continues slowly to expand, and though there is room for big improvement before anything approaching normal conditions are restored, the general trend of business is undoubtedly upward. Quite the busiest section is that devoted to electrical engineering. Foreign requirements of electrical machinery are exceptionally heavy. Inquiries received by some of the leading concerns are more numerous than a year ago, and big business is being done, sufficient in some cases to guarantee activity at works for six months ahead. Sheffield has already benefited from one large order for Colonial electrification. Other big schemes are expected to emerge in the early future. A demand is also springing up for wireless apparatus, while the reduction in telephone charges promises to act as a useful spur to business in telephone equipment. New contracts, of minor dimensions but in the bulk of considerable value, have been booked during the past week by makers of railway and tramway material. Messrs. Cammell Laird and Co. are to supply 250 all-steel goods wagons to the Assam Bengal Railway Company, and 150 similar wagons to the East India Railway Company. The approximate gross value of these contracts is 90,000*l.* They will provide three or four months' work for about 400 men at the firm's Nottingham and Sheffield factories. Business in steel tyres is also looking up. The London County Tramways have placed an order with Messrs. Henry Bessemer and Co., Limited, for the supply of 2,000, while Sheffield Corporation has agreed to take 400 at a similar rate. Home and export business in agricultural machinery and implements tends very slowly to increase. Makers of malleable castings are doing a slightly larger business than a month ago. More beater plates are required by makers of threshing machines who have booked new business with the Colonies. A marked improvement is shown in the current demand for reaper sections. A moderate tonnage is going to Russia. The demand for farm and garden tools, which was distinctly patchy at the beginning of the season, has improved, and on Colonial account edge tools, hammers and files are going away more freely. There appears to be no prospect of improvement in twist drills until Government surpluses, available at rates which come considerably below the current cost of production, are absorbed. In view of the renewed activity in the finished sections, steel-makers have ordered contract deliveries of hematite to be resumed, and have also placed orders for supplementary tonnages to cover slightly increased consumption. Stocks at works are low, and will require prompt augmentation if a further expansion in business is registered. Prices of all classes of raw and semi-finished materials are firm with an upward tendency. Quotations at works are as follows:—West Coast hematites, 5*l.* to 5*l.* 5*s.*; East Coast hematites, 4*l.* 17*s.* 6*d.*; Lincolnshire No. 3 foundry, 4*l.* 5*s.* to 4*l.* 7*s.* 6*d.*; Lincolnshire forge, 4*l.* to 4*l.* 2*s.* 6*d.*; Derbyshire No. 3 foundry, 4*l.* 2*s.* 6*d.*; Derbyshire forge, 3*l.* 17*s.* 6*d.*; bars, 12*l.* to 12*l.* 10*s.*; sheets, 16*l.* to 17*l.*

South Yorkshire Coal Trade.—All classes of house coal are stagnant. Recent reductions in price have failed to attract buyers, and further cuts of a substantial nature are anticipated. Best steam hards are in moderate request for home consumption. A slight improvement in the demand for shipment is reported. Contractors find difficulty in disposing of cobbles and nuts, the demand for bunkering purposes being on the light side. Slacks are becoming scarce, with prices firmer, though this development is due solely to short working at the pits. Furnace and foundry coke show a weak tendency, while gas coke is decidedly quiet. Quotations:—Best branch handpicked, 37*s.* to 38*s.*; Barnsley best Silkstone, 33*s.* to 34*s.*; Derbyshire best brights, 27*s.* 6*d.* to 30*s.*; Derbyshire best house, 25*s.* to 27*s.*; Derbyshire best large nuts, 22*s.* to 24*s.*; Derbyshire small nuts, 15*s.* to 16*s.* 6*d.*; Yorkshire hards, 23*s.* to 24*s.*; Derbyshire hards, 21*s.* to 23*s.*; rough slacks, 8*s.* to 10*s.*: nutty slacks, 7*s.* to 8*s.*; smalls, 2*s.* to 4*s.* 6*d.*

DEODORISING THE VAPOURS FROM REFUSE DESTRUCTORS.—According to Yandell Henderson and Howard Haggard of the Laboratory of Applied Physiology, Yale University, Connecticut, refuse destructors can be made inoffensive to the neighbourhood by drying the refuse and then mixing the vapours with chlorine in a very small percentage, which has to be determined since an excess of chlorine is as unpleasant as a bad odour. It would be hopeless to deodorise the original damp material; dried garbage hardly smells, provided it be kept dry. The chlorine is introduced into the vapour duct through a small gas pipe. In the presence of ammonia more chlorine is required than under ordinary conditions; but the deodorisation is said to be successful. The process—which is patented—has been adopted in the Municipal Garbage Plant of New Bedford, Massachussetts (*Journal of Industrial and Engineering Chemistry* June, pages 548 to 551). In this plant the Cobwell process is in use, according to which the greasy garbage is boiled in digesters with naphtha which extracts the grease which is afterwards recovered. This is economical only when a certain amount of fat is present; otherwise the garbage is merely dried and the vapour treated with chlorine. The apparatus used is that of Wallace and Tiernan, applied in water chlorination; but the paper we quote from does not give much technical information.

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

The Cleveland Iron Trade.—There is a better feeling as regards Cleveland pig iron, but improvement is slow. It is gratifying, however, to hear general expression of opinion that the worst of the depression is passed, and to learn that a few more idle blast furnaces are being re-kindled. Output is still on a very limited scale. No. 1 and siliceous iron continue quite scarce, and there seems some likelihood of one or two other qualities being anything but plentiful in the near future. Home inquiries are now fairly good, and a few moderate orders have been placed, but export business keeps quiet. A few further sales to America are reported, and Germany is negotiating for more iron. Business with Scotland has almost ceased. Merchants here are selling a little Continental iron to Scotland to the exclusion of trade in Cleveland pig. The f.o.t. makers' works or f.o.b. Tees quotations stand. No. 1 and siliceous, 95*s.*; No. 3 G.M.B., 90*s.*; No. 4, foundry, 87*s.* 6*d.*; No. 4, forge, 85*s.*, and mottled and white, 80*s.* These prices rule for all trade except transactions with customers North of the Tweed. For such business rates are based on 96*s.* 8*d.* f.o.t. Grangemouth.

Hematite.—East Coast hematite continues plentiful, but demand is improving a little, and makers expect values to firm up. The general market quotation for Nos. 1, 2 and 3 is in the neighbourhood of 95*s.*, and some producers ask a little more for home sales. No. 1 is a shilling above mixed numbers.

Output of Pig Iron.—Of the 70 blast furnaces built on the North East Coast only 28 are as yet in operation, six of which are making Cleveland pig, 12 are producing hematite, and 10 are turning out special kinds of iron.

Foreign Ore.—Business in foreign ore is extremely small, being, indeed, confined to sales of occasional cargoes. Whilst rather less would doubtless be accepted, the recognised market quotation for best rubio remains at 27*s.* c.i.f. Tees, and for good Mediterranean ores round about 23*s.* 6*d.* c.i.f. Tees is named.

Coke.—There is an abundant supply of blast furnace coke, and values tend easier, but several sellers show disinclination to materially lower prices, and whilst local consumers report that they can purchase Durham average qualities at 26*s.* 6*d.* delivered, more than that figure is asked.

Manufactured Iron and Steel.—As yet little new can be reported regarding finished iron and steel, but what slight change is noticeable is for the better. There is rather more doing in one or two steel departments, and preparations are proceeding to set inactive machinery in operation. Manufacturers, however, are still generally badly off for work. Export orders are accepted at below the following rates which rule for home business:—Common iron bars, 12*l.*; iron rivets, 14*l.*; steel boiler plates, 13*l.* 10*s.*; steel ship, bridge and tank plates, 10*l.*; steel angles, 9*l.* 10*s.*; steel joists, 10*l.*; steel billets (soft), 7*l.* 15*s.*; steel billets (medium), 8*l.* 5*s.*; steel billets (hard), 8*l.* 15*s.*; tees, 10*l.* 10*s.*; heavy steel rails, 9*l.* 10*s.*; fish plates, 14*l.* 10*s.*, and galvanised corrugated sheets, 16*l.*

THE GERMAN DYE AND CHEMICAL INDUSTRY.—The Berlin Anilin Company has done exceedingly well during 1921. The gross profits amounted to 149,464,000 marks, against 60,748,000 marks for the previous year. The available surplus amounts to 63,553,000 marks; the preference shareholders obtain a dividend of 3½ per cent. as before, whilst for the ordinary shareholders the dividend was fixed at 30 per cent. on a capital of 131,000,000 marks, against 20 per cent. on 63,000,000 marks capital in 1920; a sum of 20,000,000 marks was reserved for welfare purposes. Building operations during last year had mostly been confined to workmen's dwellings. The Baden Anilin and Soda Company, in its report, enlarges upon the immense benefit conferred upon the German community through the home mass production of nitrogene manures, which the Baden Anilin Company had called into existence, the more so as German agriculture at present would have to pay about two and a-half times as much for imported as for home-produced manure. Owing to the Oppau explosion the working of the year results in a deficit. In the matter of dye-stuffs the demand which flagged towards the middle of 1921 in all countries, improved during the last quarter of the year, more especially as regards foreign markets. The shortage of coal and coke, principally caused by the requirements for reparations, has made itself seriously felt during the past year. This has more especially affected the manufacture of ammonia products, which had made it impossible to satisfy all demands. As a result the farmers had been compelled to import some manure. The company's capital, expressed in gold marks, has been tripled since 1914, whilst the dividend has decreased. On the amount of ordinary shares which, expressed in gold marks amounts to 101,000,000 marks gold, the dividend comes out at 2½ per cent. The company holds shares in other concerns amounting to 253,426,000 marks. The Reich authorities have sanctioned a rise of 27 per cent. in the price of nitrogene products, and the alkali industry is now demanding higher prices, as the cost of production has risen very materially, both in the matter of higher coal prices and wages (the latter having been increased 36 marks per day and shift), higher railway rates, &c., altogether an increased burden for the alkali industry of more than 1,000,000,000 marks. To meet this the works demand that an increase of 34 per cent. should be sanctioned.

NOTES FROM THE SOUTH-WEST.

CARDIFF, Wednesday.

The Coal Trade.—The official return of the volume and value of the coal trade in May last are the best since the termination of the national strike nearly 12 months ago. It shows that shipments at the ports of Cardiff, Newport, Swansea and Port Talbot amounted to 2,213,168 tons, valued at 2,794,603*l.*, an increase of 464,369 tons in volume and 667,469*l.* in value when compared with April. The most gratifying feature of the return was the continued advance in selling prices, for it shows that the 1,411,648 tons of large steam coal exported averaged 26*s.* 10*d.* per ton compared with 26*s.* 8*d.* in April and 25*s.* 10*d.* in March, while the 529,202 tons of steam small averaged 18*s.* 7*d.* per ton compared with 17*s.* 11*d.* in April and 17*s.* 9*d.* in March. Taking the different ports separately it shows that steam small shipped from Cardiff averaged 18*s.* 6*d.* per ton in May against 17*s.* 9*d.* in April; throughs 21*s.* 11*d.* against 21*s.* 5*d.*, and large, 27*s.* against 27*s.* 2*d.* Steam smalls shipped from Swansea averaged 19*s.*, compared with 17*s.* 2*d.* in April; throughs, 19*s.* 7*d.*, the same as in April, and large, 26*s.* 2*d.* against 25*s.* 9*d.*, while anthracite smalls improved from 20*s.* 9*d.* in April to 24*s.* 1*d.* in May, and large from 33*s.* 1*d.* to 37*s.* 5*d.* Of the total shipments 664,600 tons went to France, 345,000 tons to Italy, 386,700 tons to South America, and 279,700 tons to British coaling depots. Since the end of May there has, however, been a decided change in the condition of the coal market. Inquiries have dwindled to very small dimensions and prices have also slumped. Towards the close of last month second Admiralty large coals were selling at 28*s.* and best steam smalls at 19*s.*, but now it is possible to secure the former at 26*s.*, a drop of 2*s.*, and the latter at 18*s.*, a fall of 1*s.* per ton. Even at these prices buyers are not coming forward and numerous stoppages have taken place in the coalfield through lack of wagons, consequent on trucks being held up at the docks under load because of the lack of remunerative trade. The general position at the moment is anything but bright, for it is impossible for colliery companies to reduce prices further without suffering more appreciable losses. In fact many are now only carrying on on bank overdrafts.

Coal Trimmers' Tariffs.—The Shipping Federation, representing the shipowners of the United Kingdom, have made an application to the National Transport Workers' Federation, representing the coal trimmers and coal tippers, for a further reduction of 25 per cent. in the National Coal Trimming Tariff, which if agreed, will mean a reduction of 50 per cent. on the base rates set out in the tariff scale of August, 1920. The rates would then be about 20 per cent. above the pre-war levels. The actual earnings of the trimmers who are paid by results, would, however, not be reduced to the extent indicated by the 50 per cent. reduction, for the average rate of shipments have been increased at Cardiff, Penarth and Barry for 12,000,000 tons per annum in the period October, 1919, to September, 1921, to 19,000,000 tons per year in the first five months of this year, an increase of about 58 per cent.

LANDING OF AEROPLANES IN FOG.—We are informed that the Technical Commission of the Royal Dutch Aero Club are offering a prize of 3,000 guilders, for the best instrument, or set of instruments, which will indicate to the pilot of an aeroplane flying in a dense fog his height from the ground or the water. The indication must be independent of any installation on the ground or water, and also of atmospheric pressure. The error of the indication must not exceed 1 m. for heights of less than 10 m. and must not be greater than 10 per cent. for heights ranging from 10 m. to 300 m. The indication must take place in an aeroplane, the velocity of which has a horizontal component of from 10 m. to 50 m. per second and a vertical component ranging from zero up to 5 m. per second. The competition is open to persons of all nationalities and drawings, descriptive matter, &c., must reach the jury, at the offices of the Royal Dutch Aero Club, Heerengracht 13, The Hague, Holland, not later than March 15, 1923. Further particulars of the conditions to be complied with can doubtless be obtained from the Secretary of the Club at the address above mentioned.

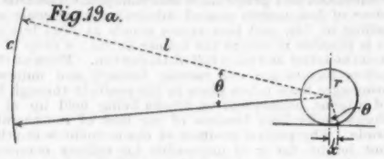
CONTINUOUS SPECTRUM OF MERCURY VAPOUR.—That mercury vapour will give a continuous spectrum was observed by Warburg in 1890 and since by various other observers, but the extended study of this spectrum, described by C. D. Child, in the *Astrophysical Journal*, of May, is probably new. Passing the electric discharge through an inverted U-tube, containing liquid mercury at the bottom of both the limbs, Child noticed the green vapour of mercury, a continuous spectrum and, at the same time, a line spectrum near the cathode. One of the small mercury troughs served as reservoir, the other as a trap, that limb being connected to the pump. The two troughs must be kept at about 120 deg. C.; the upper portion of the tube should be hotter, but not above 300 deg.; the current density should be very low and the tube must not be too narrow, since a stricture has the effect of raising the current density. The discharge should be produced by a Wimshurst machine, or a transformer, not by a coil with condensers in circuit. The mercury need not be of more than ordinary purity, but other gases, especially air, should only be present in traces. The nature of the electrodes and of the tube material seemed to be unimportant. From the low ionisation potential observed it is concluded that the spectrum, which resembles the fluorescence spectrum, is due to mercury molecules, not to atoms.

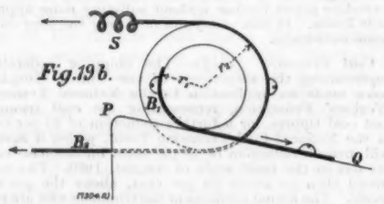
THE MECHANICAL DESIGN OF SCIENTIFIC INSTRUMENTS.*

(*Continued from page 764.*)

Friction. Knife-Edges.—Passing to the indicators of the forces we desired to measure, Professor Pollard pointed out that friction between the co-acting parts diminished the accuracy of the observations, and the magnitude of that friction was unknown and liable to sudden alterations owing frequently to unsuspected causes. There was always friction with rolling or sliding contact, but that friction could be made small mostly relative to the movement of the indicator. In Joule's mounting of the dip needle, the needle, instead of rolling on agate planes, was slung on two filaments of silk, the ends of the filaments being attached to the arms of a delicate balance. To keep the needle in neutral equilibrium as it rolled upon the filaments its centre of mass should neither rise nor fall; the arms of the balance should hence be equal, and the filaments at right angles to them.

In turning pairs the friction might be diminished by reducing the size of the axle, by supporting the axle on friction wheels, by reducing the area of contact to that of a point in a pivot cap or jewel, or by placing hardened balls between the axle and its bearing. For some rotational movements knife-edges were used. In

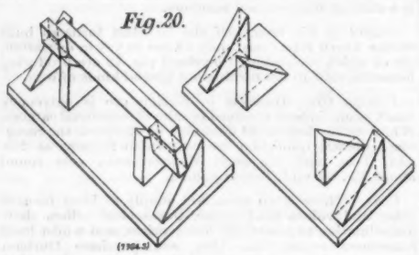


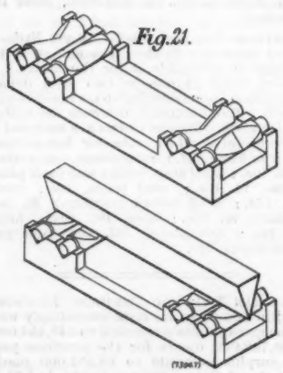


balances each knife-edge rested on a plane and in reality the edge was cylindrical; thus rolling friction was introduced. Although the use of levers magnified any errors consequent upon wear and increase of radius, knife-edges were the best means at disposal for securing small rotations about a definite axis when loads were not excessive. Since a knife edge could slip about on its plane and rotate about the vertical as well as about its edge, it had 4 deg. of freedom; it required only two surfaces of constraint, therefore, and might be replaced by the contact of two steel balls rigidly connected together bearing on a plane. Such an edge was useful when the radius of the rolling edge was required to be accurately known. But this radius might be too small for the constructor. The Talymin comparator of Mr. W. Taylor, used for quickly checking the dimensions of manufactured parts to $\frac{1}{10000}$ in., met that difficulty. Fig. 19 explains the principle of this beautiful instrument. When a cylinder of small radius r rolled on a plane through the distance x, the pointer of length l attached to the cylinder would cover the scale distance c, such that $r/x = l/c$. Now if $x = 0{\cdot}0001$ in., $l = 4$ in. and $c = 0{\cdot}04$ in., r should be $0{\cdot}01$ in.; but a roller of that dimension could not be made. Two coaxial cylinders of radii r_1 and r_2 (larger) were hence turned out of the same rod; the bands B_1 and B_2 were secured to the cylindrical portions of r_1 and r_2; B_2 was connected to a plunger at the end of which was the measuring anvil, and the plunger was pulled by one spring in the direction of the arrow marked, and in the opposite direction by the weaker spring S. The cylinder r_1 and B_1 with it rolled upon the plane P Q. If the cylinders rolled through an angle θ (as indicated by the pointer), the band B_2 moved through the distance $r_2\theta$; but the cylinder r_1 also rolled on its plane carrying B_2 through $r_1\theta$ in the opposite direction. The total band movement was thus $(r_2 - r_1)\theta$, and the difference $(r_2 - r_1)$ could be made as small as one pleased. In the actual instrument P Q was inclined so that the tension of the bands kept the roller in contact with it; the small correction of the formula required for this reason could be definitely calculated. This device might profitably be used in the aneroid altimeters of the Air Ministry, the diaphragms of which could not recover quickly when the aeroplane was rapidly descending; one might also stiffen the diaphragm, but the diaphragm movement would then become too small. Professor Pollard reverted to this point.

For some purposes two more degrees of constraint had to be imposed upon knife-edges, which then had only 2 d.f. left, viz., a rotation about the edge and a translation along it, to be limited by stops; the knife edge had then to bear against four surfaces. A geometrical design of such a knife-edge was embodied in Sir H. Darwin's Rocking Microtome (Fig. 20), in which, however, the two outermost edges would leave their planes, and the geometrical relations would be destroyed, if there were bending under excess of load. This defect was overcome by Sir Horace Darwin by making the knife-bearing planes capable of rotation about axes at right angles to the direction of the edge; when the edges bent, the planes rotated, maintaining line-contact with the edges; Fig. 21 explains this beautiful design.

Variance, Accuracy and Sensitivity.—In the third lecture Professor Pollard dealt with variance in relation to accuracy and sensitivity. An instrument was accurate when its indication agreed with the quantity being measured, and sensitive when a change in the quantity measured was accompanied by a change in the indications. Perfect accord being impossible to obtain we had to make "corrections" for friction, wear, influences of pressure, temperature, humidity, rate of





operation, &c., and normally uncontrollable variations, at any rate, in the case of laboratory instruments. Numerically instrumental accuracy was expressed by defining the error or correction for various values of the quantity being measured. The error from whatever source, divided by the true value, might be termed the relative or specific inaccuracy at a given reading; it was given a negative sign for ease in application. The reciprocal of this inaccuracy, viz., the specific accuracy, was not of value in the ordinary use of the instrument, but of service in rating its performance. Sensitivity had for particular instruments, especially those read by null methods, often been expressed as the smallest change in value of the measured quantity to which the indicator perceptibly responded.

So expressed the term was loose and unscientific, since it introduced the personal factor and did not distinguish between insensitiveness and sluggishness or want of response. For example, the sensitivity of a balance was long defined as the smallest added load that would move the pointer; analytical-balance makers even now expressed sensitivity as "turning to so many milligrams." The beam, however, might be sluggish and might turn to a smaller load if left to itself long enough. To state the distance through which the pointer moved for unit load was not scientific either; for that sensitivity could be improved by making the pointer longer. We should state the angular displacement for change of unit load. In actual measurements of sensitivity the deflections of the pointer should be small, since sensitivity might vary over the range of the scale. Hence Professor Pollard defined sensitivity as the rate of displacement of the indicating element with respect to change of the measured quantity, viz., $\delta\theta/\delta m$. But owing to friction some definite change δm in the measured quantity might fail to produce any change $\delta\theta$ in the indication; we should then have zero sensitivity at some point in the measured quantity-indication curve though the curve had a definite slope at that point. For this reason the distinction between sensitivity and want of response became necessary. Less precise instruments often showed periods of inaction due to friction between moving parts and the taking up of slack. There was thus instrumental "passiveness" as distinct from instrumental insensitiveness, as Schlink first pointed out. Passivity was the ratio of the least change δm in the measured quantity producing instrumental response to the initial value m of the measured quantity. In this definition the notion of perceptible movement was retained, since the passiveness evidenced by delayed response had been overcome, so soon as any motion whatever of the indicating element had taken place.

Apart from these variations due to changes in the measured quantity, there were others, intrinsic to the instrument, and covered by the term "variance." Variance was defined as the range at any given value of the quantity m, of variation in the reading which might be exhibited by the instrument under repeated application of the same value of the quantity, after steady reading had been obtained, the environment remaining unchanged. The specific variance or

Fig.22. HYSTERESIS LOOP OF AUTOMATIC WEIGHING SCALE OF THE CAM-PENDULUM TYPE (COMPRISING NO ELASTIC FORCE-MEASURING ELEMENTS)

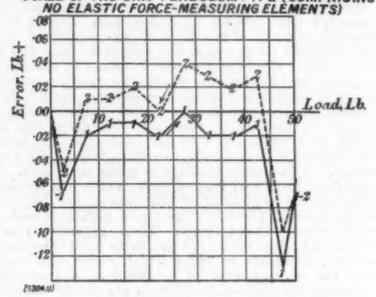
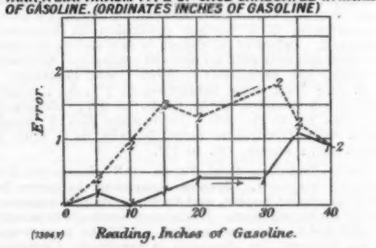


Fig.23. HYSTERESIS LOOP OF DEPTH GAGE FOR GASOLINE TANK, A DIAPHRAGM TYPE OF GAGE GRADUATED IN INCHES OF GASOLINE. (ORDINATES INCHES OF GASOLINE)



"variancy" was the ratio of this range to the value of the measured quantity. Variance overlapping passiveness was in reality the range of uncertainty of indication when all the causes of variation (save those inherenf in the instrument) were eliminated. That factor was rarely determined in tests, but its investigation would certainly expose instrumental imperfections of unexpected importance.

In the case of the usual direct-reading instrument the variance was disclosed as the displacement observed between the upward and downward branches of a hysteresis loop when the instrument was subjected to a complete cycle of operation. Those curves afforded information regarding defects of design and workmanship. The Schlink hysteresis loop of Fig. 22 was that of an automatic weighing scale of the cam-pendulum type in which the load was balanced by the turning moment of a pair of oppositely-rotating pendulums mounted on ball bearings. The aberrations of the increasing readings were reflected in the curve of decreasing readings, with a tendency to wider separation at the middle of the load range. The hysteresis was certainly not due to the elastic strain, as there were no elastic force elements, though no doubt the elastic strain of the co-acting elements contributed to a small amount; the sources of this hysteresis loop were all expressible as backlash or were analogous to it. The case of Fig. 23 was different. It was the hysteresis loop of a depth gauge of the diaphragm type for gasolin tanks, and the variance was obviously due to want in elasticity of the diaphragm. The ordinates marked inches of gasoline. This type of variance was present in all instruments making use of a spring element in equilibrating the changes in the measured quantity; the changes of shape of the spring elements were to a certain extent irreversible.

To be continued.)

* Abstract of three Cantor Lectures, delivered in February and March last before the Royal Society of Arts by Professor Alan F. C. Pollard, A.M.I.E.E., F.Inst.P., Department of Optical Engineering, Imperial College of Science and Technology, South Kensington.

ELECTRIC LOCOMOTIVES.*

By Sir VINCENT L. RAVEN, K.B.E., Vice-President.

THE subject of electric locomotives is attracting a good deal of attention at present in railway circles, and a number of papers have been written, mainly in the United States and on the Continent, describing various designs which have been worked out for different purposes. Little has been published, however, in England during the last few years, in spite of the fact that a good many new locomotives have been built and put into service for various countries. This is the more to be regretted as England about 100 years ago was the birthplace of the steam locomotive. It is only fitting, therefore, that English railway engineers should take an active interest in the design of locomotives which, while not superseding the older machine, may now, at all events, be regarded as a definite factor in the future development of British as well as foreign railways.

The complete design of an electric locomotive is a combination of mechanical and electrical engineering. The mechanical portions of the locomotive definitely affect the design of the electrical portions and *vice versa*, and each portion has to be worked out in detail, quite apart from the determination of the general scheme. It is not proposed in this Paper to go into the many detail points of mechanical and electrical design which are, of course, of great interest to many engineers, but rather to deal with the more general questions of (1) the requirements which any locomotive must be designed for; (2) the various designs which have been worked out to meet these requirements; (3) the advantages and disadvantages of the various designs which have been completed.

There are broadly three classes into which locomotives on most railways may be divided according to the nature of the work to be performed or the class of train to be hauled, namely :—

(1) Shunting; (2) freight or goods; (3) passenger.

It is not, of course, practicable to confine any class of locomotive strictly to the duties for which it is primarily designed. For instance, it is very desirable that a passenger locomotive should be able on occasion to haul goods trains, and freight locomotives frequently have to carry out a certain amount of shunting at intermediate stations. In fact one of the most important points to be attended to in considering any design is the question whether the locomotive is well adapted to deal economically and conveniently with two or more different classes of traffic. Naturally, beyond a certain point, such adaptability may cost more than it is worth. How far it is advisable to go in this direction is a matter for individual judgment. This is referred to later.

Shunting Locomotives.—Locomotives of this class are required principally for marshalling trains in goods yards. There is no need for them to be capable of running at high speed. A maximum of 25 m.p.h. will be ample. They should, however, be suitable for moving the heaviest trains in use. The tractive power must, of course, be limited by the strength of the standard drawgear, and, on the British railways at all events, this consideration will determine the weight on the drivers.

On British railways it is not possible to go much higher than 30,000 lb. drawbar pull and an adhesive weight of 60 tons to 65 tons should be sufficient. Compared with steam locomotives usually employed in goods yards this is a substantial increase. It is, however, a great advantage to have plenty of weight on the drivers in order to start trains rapidly and thus speed up shunting operations. On other railways, such as those in the United States, where the drawbars can stand much greater pulls, rather more weight on the drivers can be usefully employed. For example, the New York, New Haven and Hartford Railroad uses a number of electric shunting locomotives in their Oak Point, Westchester, Stamford and Harlem River yards. These locomotives have a weight of 71½ tons all on the drivers. On the other hand, the Chicago, Milwaukee and St. Paul Railroad has four electric shunting locomotives, weighing 64 tons.

For this class of locomotive there is no question of complicating the design by considerations of steady running, adaptability to other classes of traffic, &c. The design should be as simple as possible and, if practicable, the whole weight of the locomotive should be on the driving-wheels. For anything in the neighbourhood of 60 tons it is necessary to divide the weight between four axles, in order not to exceed the permissible axle loading.

The simplest arrangement is undoubtedly the double bogie design, each bogie carrying a pair of geared motors. This is from several points of view the most satisfactory; the construction is cheap, and the maintenance easy, due to the facility with which a bogie can be removed for overhaul or repair of the motors and a spare bogie substituted. The author sees no reason why this general design should not be regarded as standard for this class of locomotive.

The buffers and drawgear may be mounted on the body, and the tractive effort transmitted from the driving-wheels through the bogie centres; or the drawgear may be fixed to the outer end frames of the bogies and the inner end frames connected together by an articulating joint, thus removing all buffing stresses from the body.

The North Eastern Railway have had in use on their Quayside line at Newcastle for 17 years two shunting locomotives which have given extraordinarily good results. They are of the double bogie type with buffers and drawgear mounted on the body. The following are a few particulars :—

Total weight	55 tons.
Length	38 ft.
Wheel diameter	36 in.
Bogie wheelbase	6 ft. 6 in.
Distance between bogie centres ...	20 ft. 6 in.
Number of motors	4.
H.P. per motor	160.

Duty.—The locomotive is capable of hauling a load of 335 tons on the level at 14 m.p.h., and of starting up a gradient of 1 in 25 with a trailing load of 166 tons, and of hauling this load up the same gradient at 9·5 m.p.h.

These locomotives, of which an outline drawing is shown in Fig. 1, have been in service since 1905, and they have only been in the shops three times for thorough overhaul.

Their daily duty consists of about 14½ hours shunting work and two hours running with trains. Including the time for preparing, stabling, running to and from the shed, their daily service occupies about 18 hours and, if required, they could do more. For the whole of the year 1921 the average cost per engine for repairs, inspection, preparing, cleaning, &c., was 103*d*. This figure is rather high, as it included some special repairs to one of the locomotives which would not be required in an ordinary year. It may be compared with the corresponding figure for the steam locomotives doing the same class of work, which for the year 1921 would be about £610.

The particulars of the shunting locomotives on the New York, New Haven and Hartford Railroad and the Cincinnati Milwaukee and St. Paul Railroad mentioned above, are as given in the table above.

—	N.Y., N.H. and H. R.R.	C., M. and St. P.
Type of locomotive	Articulated bogie	Double bogie not articulated
System of electrification ..	Single-phase 25 cycles	D.C.
Voltage	11,000	3,000
Drive	Geared quill	Straight gear
One hour rating :—		
Tractive effort .. .. lb.	23,200	21,400
Speed .. .. ..m.p.h.	12·2	11·5
Maximum safe speed ..m.p.h.	25	35
Diameter of driving wheels ..	63 in.	40 in.
Total weight .. .. tons	71½	64
Bogie wheel base	7 ft.	8 ft.
Distance between bogie centres	16 ft. 6 in.	22 ft. 4 in.
Number of motors	4	4
Horse-power per motor, 1 hour rating	150	165

Some particulars of the duty performed by the New York, New Haven and Hartford Railroad shunting locomotives have been published recently, from which it would appear that the average daily tonnage dealt with per locomotive at the Oak Point Yard is about 16,000 and the monthly mileage about 4,500. The locomotives are kept in service 24 hours a day and are normally given a light inspection, requiring half a day, after 2,500 miles. A number of these locomotives have worked 24 hours a day for 30 days without interruption.

Freight or Goods Locomotives.—The conditions which govern the design of freight locomotives differ in different countries, mainly in respect of the strength of the standard drawgear and the use of power brakes on the goods wagons. On British railways, as already mentioned, it is useless to design a locomotive for more than about 30,000 lb. tractive effort, whereas in the United States there is no objection to 120,000 lb. pull. In other countries the drawgear strength may be intermediate between these figures; for example, in South Africa a pull of 60,000 is considered practicable. The question of what speed to provide for is a point for careful consideration. One of the great advantages of electrification on a railway is the possibility it affords of speeding up the slow-moving traffic. Apart from special conditions, only those lines will be electrified on which there is a fairly dense traffic. On many of our railways, the traffic is not only dense, but is congested. This is mainly due to the precedence which has to be allowed to express passenger trains, while goods trains have to take such opportunities as offer of working through from station to station in the intervals between passenger trains. By increasing the average speed of the goods trains and the length of lie-over at stations can in general be greatly reduced, as shorter intervals can be utilised. When a line reaches the point of congestion, the capacity can be increased by quadrupling or by electrification. The former is a very costly matter, and even if the congestion is relieved in this way the many advantages obtainable by electrification are not secured. It is important, therefore, that the speed of goods trains should be raised as much as is practicable. On the British railways, due to the absence of power-brakes on the wagons, the speed on the level must not exceed about 35 m.p.h. and must be less than this on falling gradients, in order that the train may be sufficiently under control to stop when required by signal. The only practicable way, therefore, to effect any substantial increase in the average speed is to increase the speed up the gradients. This can easily be done by providing a sufficiently powerful locomotive and designing it for the speed required.

The author considers that the standard freight locomotive should be capable of taking a normal train up the ruling gradient on any ordinary line in Great Britain at about 25 m.p.h. This should enable an average speed of 30 m.p.h. to be maintained, which approximates to the speed of the local passenger trains. All trains, except the few passenger expresses, would then travel at approximately the same speed, and the traffic delays would thereby be cut down to the minimum. Where conditions are different, as in the United States, it is economical to have much heavier trains than in Great Britain. For example, the Pennsylvania Railroad have built an experimental locomotive of 4,800 h.p. capacity, which is intended, with the assistance of a similar locomotive pushing at the rear, to take a train of 3,500 tons up a 1 in 50 gradient 12 miles long at about 20 m.p.h., or a train of 5,600 tons up a 1 in 100 gradient 24 miles long at about the same speed. Further particulars of this experimental locomotive are given at the bottom of the first column of page 797.

A good many designs have been worked out in different countries, and descriptions of the most important follow :

(1) The North Eastern Railway in 1914 built 10 freight engines for working the mineral traffic on the Shildon-Newport branch line. These are of the double bogie type, as shown in Fig. 2, the two bogies being articulated, carry the buffers and drawgear on their outer ends. The following are some of the particulars of these engines :—

Gauge	4 ft. 8½ in.
Voltage and system ...	1,500 d.c.
Drive	Straight twin gear.
Total motor rating ...	One hour, 1,100 h.p. Continuous 635 h.p.
Tractive effort ...	One hour 19,000 lb. Continuous 10,400 lb.
Speed	One hour 20·5 m.p.h. Continuous 22·8 m.p.h.
Length over buffers ...	39 ft. 4 in.
Total wheel base ...	27 ft.
Rigid wheel base ...	8 ft. 9 in.
Width overall ...	8 ft. 4 in.
Height (pantograph down)	13 ft. 1 5/16 in.
Diameter of driving wheels	4 ft.
Total weight of locomotive	74 tons 8 cwt.
Weight per driving axle	18 tons 12 cwt.
Weight of electrical equipment	24 tons 5 cwt.
Weight of mechanical equipment	50 tons 3 cwt.
Approximate height of centre of gravity ...	4 ft. 6 in.

These engines deal with the mineral traffic between the gathering centre at Shildon and the sidings at New-

Fig. 1. NORTH EASTERN RAILWAY. ELECTRIC FREIGHT LOCOMOTIVE. NEWCASTLE QUAYSIDE BRANCH. 0-4 +4-0 TYPE.

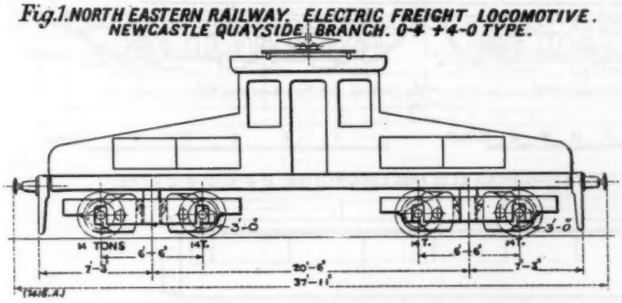
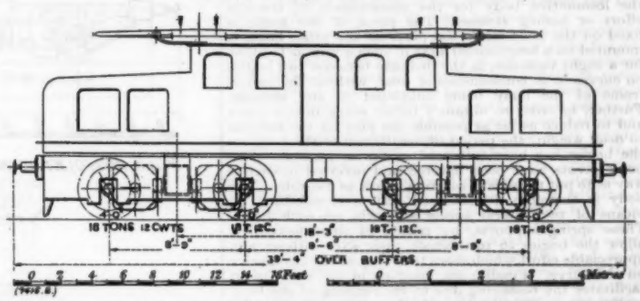


Fig. 2. NORTH EASTERN RAILWAY. ELECTRIC FREIGHT LOCOMOTIVE. GEARED DRIVE. TOTAL H.P. 1,100. TOTAL WEIGHT, 74 TONS 8 CWT. 0-4 +4-0 TYPE.



* Paper read at the Paris Meeting of the Institution of Mechanical Engineers, June 14, 1922).

port, five electric engines being capable of doing the work formerly done by 13 steam engines. It may be of interest to mention the cost of repairs, shed charges, &c., for these electric locomotives. Last year was exceptional as the traffic on this branch was abnormally low, due to the coal strike. It is better, therefore, to take the year 1920 which may be considered a fairly normal year. The total cost for repairs, inspection, preparation, cleaning, &c., for the electric locomotives for the year 1920 came to 1¼d. per engine mile, of which repairs amounted to a little more than 1d. and shed charges a little less than ¼d. These figures may be compared with corresponding figures for the same year for steam engines doing similar work, namely, about 11¼d. per engine mile total, of which the repairs alone would cost about 8d., and the shed charges about 3¼d. The present-day cost, of course, is considerably below those ruling in 1920, and the author estimates that at the present time the corresponding figures for repairs, shed charges, &c., would be about 30 per cent. lower.

Locomotives of similar general design are in use on several railways in the United States, namely :—

The Baltimore and Ohio Railroad.
The Great Northern Railroad.
The Michigan Central Railroad.
The Butte Anaconda and Pacific Railroad.

The Midi Company is building 50 electric locomotives, 30 of which are for omnibus passenger trains and 20 for goods traffic, and in addition it is building two experimental locomotives for high speed work. The 30 passenger train locomotives only differ from the 20 locomotives for freight work in respect of the gear ratio. The locomotives are of the type BB, that is to say, they are mounted on two bogies each of which has two motor driven axles. The total weight of the locomotive is 72 tons, and the capacity of the motors is 1,000 h.p. continuous and 1,400 h.p. on the one-hour rating. The passenger locomotive can attain a speed of 80 km. (49·7 miles) per hour, and the goods locomotive 60 km. (37·2 miles) per hour.

The mechanical construction of these locomotives contains certain new features. The draw-hook and the buffers are mounted direct on the bogies, and these bogies are articulated in order to avoid using the structure of the locomotive body for the transmission of tractive effort or buffing stresses. The pivot of one bogie is fixed on the body while the pivot of the other bogie is mounted on a longitudinal slide in such a way as to allow for a slight variation in the distance between two bogies on curves or in consequence of wear, without the underframe of the body being subjected to any stresses. Further, in order to obtain a better entry into a curve and to reduce as far as possible the play on the rail due to dead weight, the period of oscillation of the body on the bogies has been increased as far as possible. The bogie pivots have been lowered and inverted in such a way as to put the axis of rotation as low as possible. The body is therefore de-stabilised and is re-stabilised by means of two lateral spring supports on each bogie. These spring supports, by reason of their flexibility, allow the bogies to turn about their axis without any appreciable effort which eases the entry of the locomotive on the curve. Finally, the lowering of the bogie pivot facilitates the balancing due to the running of the locomotive over irregularities of the track. Each axle-motor is connected to its axle by twin single reduction gearing. The gear wheels are fixed directly on the centres of the driving wheels in order to avoid any abnormal fatigue of the axles. The pinions are mounted on the two ends of the armature shafts of the motors.

In regard to the electrical equipment, the bogie motors are supplied direct with continuous current at a pressure of 1,500 volts. Their capacity is 250 h.p. continuous and 350 h.p. on the one-hour rating. They are arranged for forced draught. The passenger locomotives can exert the power corresponding to their continuous rating by shunting the field windings between 50 km. and 74 km. (31 miles and 46 miles) per hour. For the goods locomotives the continuous rating, namely, 1,000 h.p., is available in the same way between the limits of speed of 30 km. and 40 km. (18·6 miles and 24·8 miles) per hour.

The locomotives BB, both the passenger and freight locomotives, are designed for regenerative braking, and on any given gradient are able to haul a train of the same tonnage as can be hauled up the same gradient by the motors at their one-hour rating. All the locomotives are fitted with multiple-unit control. The control apparatus consists of two cam-shaft controllers worked by auxiliary motors. Each motor possesses its own cam-shaft and constitutes, therefore, an independent unit. These camshafts control the working of the motors in all series, and parallel positions, but do not regulate the working when the fields are shunted.

The auxiliary motor is controlled from each of the driver's compartments, one at each end of the locomotive. The power for the control circuits and for the auxiliary motor is supplied at 120 volts from a motor generator. This motor generator comprises a direct current 1,500 volt motor which drives the generator for providing power for auxiliary purposes at 120 volts, and a variable voltage generator for excitation while regenerating, also two fans for the forced cooling of the main motors. The auxiliary generator is used also for the supply of the necessary current for lighting the train and for heating the locomotive alone.

Each locomotive is fitted with a mercury watt-hour meter which records during the periods of regeneration. This meter is used not only to record the energy consumption of each machine, but also to interest the driver in economising the power consumption. In addition to the regenerative braking each locomotive is fitted with a Westinghouse brake, also with a separate brake for the locomotive alone and a hand brake. The express locomotives will be of the type 2 C 2, that is to say, will possess three driving axles and two bogies. The one-hour rating of each locomotive is 2,250 h.p. The Midi Company is only building two of these locomotives, but these contain certain specially interesting features for experimental purposes.

Each locomotive will be equipped with three double vertical motors, each one being geared to a driving axle by means of double gearing, a hollow shaft and spring coupling. The two armatures of each double motor rotate in opposite directions so as to neutralise their gyroscopic effect. The diameter of the driving wheels will be 1,750 mm. (5 ft. 9 in.).

Each bogie motor will take power at 500 volts, and in normal working with the motors in parallel three armatures will be connected in series. For series working all the six armatures will be connected in series. These locomotives will be capable of giving their full output at a speed of 90 km. (58·8 miles) per hour and will be able to maintain the same output up to 120 km. (74·5 miles) per hour by means of shunting the motor fields. The limiting speed of the locomotives will be 130 km. (80·7 miles) per hour.

The motors will be controlled by camshaft controllers just as in the BB locomotives, and will be fitted for multiple-unit control. A motor generator reducing from 1,500 to 120 volts will supply the direct current necessary for the different auxiliary services. The high speed locomotives will not be arranged for regenerative control, as they have only to run on lines where there are no severe gradients.

A very similar design is employed by the Chicago, Milwaukee and St. Paul Railway for their freight engines. The method of transmitting the power from the motors to the driving-wheels is precisely the same, namely, by single reduction twin-gearing, but the mechanical arrangement of the trucks is different, one of the main trucks containing a guiding bogie as well as the two driving axles. A general view of a pair of these locomotives is shown in outline in Fig. 3, and some of the principal particulars of the design are given in the table at the top of the next column.

Gauge	4 ft. 8½ in.
Maximum tractive effort ...	132,500 lb.
Voltage	3,000 volts d.c.
Continuous tractive effort ...	71,000 lb.
Length overall	112 ft. 0 in.
Total wheel base	102 ft. 8 in.
Width overall	10 ft. 0 in.
Height, pantograph locked down	16 ft. 8 in.
Rigid driving wheel base ...	10 ft. 6 in.
Rigid guiding wheel base ...	6 ft. 0 in.
Diameter driving-wheels ...	52 in.
Diameter guiding truck wheels	36 in.
Total weight	257 tons.
Weight on drivers	200 tons.
Weight per driving axle ...	25 tons.
Dead weight on driving axle ...	7¼ tons.
Weight per guiding axle ...	14 tons.

Fig. 3. CHICAGO, MILWAUKEE AND ST. PAUL RAILROAD. ELECTRIC LOCOMOTIVE. GEARED TYPE.

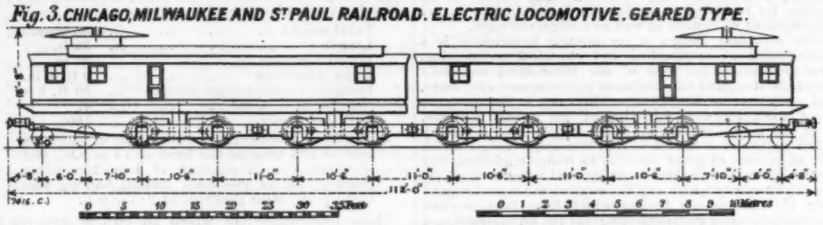


Fig. 4. PAULISTA RAILWAY. ELECTRIC FREIGHT LOCOMOTIVE. 0-6-0 + 0-6-0 TYPE.

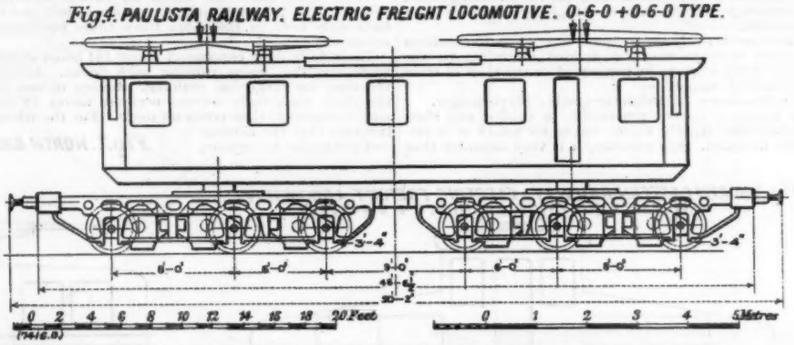


Fig. 5. NORFOLK AND WESTERN RAILROAD. ELECTRIC LOCOMOTIVE. 2-4-0+0-4-2 TYPE.

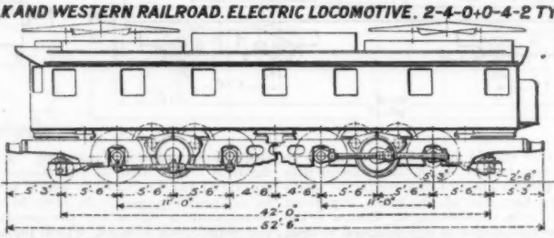
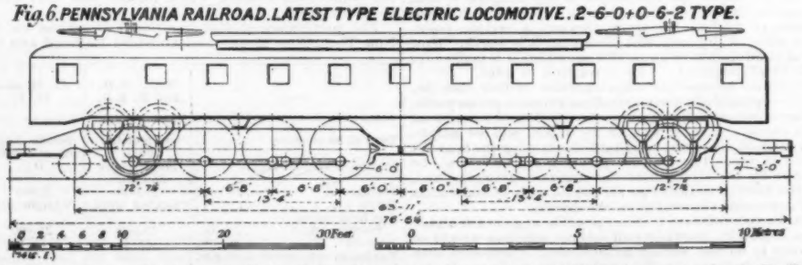


Fig. 6. PENNSYLVANIA RAILROAD. LATEST TYPE ELECTRIC LOCOMOTIVE. 2-6-0+0-6-2 TYPE.



3. A recent design of freight locomotive for the Paulista Railway in Brazil is based on the use of two articulated bogies, but differs from the ordinary double bogie locomotive in that each bogie contains three driving axles and three motors. This arrangement, which is of interest in several ways, may be regarded as a development of the older design for the purpose of obtaining a greater tractive effort than is possible with four driving axles without any substantial departure from the simple method of drive by individual motors geared to the axles. The use of six motors enables the speed to be controlled over a wide range. The motors can be grouped—(1) all in series ; (2) three in series, two in parallel ; (3) two in series, three in parallel. With each grouping, two speeds can be obtained by suitable alteration to the strength of the motor fields. Thus six different speeds, ranging from about 6 miles per hour to 21½ miles per hour, can be obtained with the same tractive effort of about 30,000 lb. Provision is also made for the use of regenerative braking by converting the motors into generators when the train is descending a gradient.

The mechanical parts and electrical equipment of the locomotive are designed so that ultimately, that is, when all the rolling-stock has been equipped with M.C.B. couplers, two locomotives may be coupled up

and operated as a single locomotive. The general arrangement is shown in Fig. 4, on the opposite page, and the principal particulars are as follows :—

Type	0-6-0 + 0-6-0.
Electrical system	Direct current.
Voltage	3,000.
Total weight	104·6 tons.

	One hour rating.	Continuous rating.
Capacity of locomotive	1,680 h.p.	1,350 h.p.
Tractive effort	29,400 lb.	21,600 lb.
Speed	21·4 m.p.h.	23·4 m.p.h.
Maximum safe speed		42 m.p.h.
Maximum tractive effort ...		58,500 lb.
Track gauge		5 ft. 3 in.
Fixed wheel base		14 ft.
Total wheel base		37 ft.
Length over buffers		50 ft. 2 in.
Wheel diameter		3 ft. 4 in.

4. The locomotives employed by the Norfolk and Western Railroad for heavy mineral traffic through the Elkhorn tunnel are also of the double bogie design. The method of transmitting the power from the motors to the driving-wheels is, however, quite different from the arrangement adopted in the examples referred to above. The transmission is effected by connecting the two driving axles on each bogie to a jack-shaft between them through cranks and coupling-rods. The jack-shaft is driven by a pair of motors mounted on the bogie frame through single reduction gearing, the two pinions meshing with a single gear-wheel mounted on the jack-shaft. The arrangement is shown in outline in Fig. 5, on the opposite page, and the following are a few of the principal details of the design :—

System	Single phase 25 cycles.
Voltage	11,000 volts
Gross weight per engine ...	245 tons.
Weight on drivers	59,000 lb.
Capacity of motors (1 hour) ...	3,000.
Capacity of motors (continuous)	2,600.
Tractive effort corresponding to the one hour rating	87,000 lb.
Speed at this tractive effort ...	14 m.p.h.
Total length of double locomotive	105 ft. 8 in.
Rigid wheel base	11 ft.
Number of motors per double locomotive	8.

5. The same method of power transmission has been adopted, but with a somewhat different wheel arrangement, for the experimental freight locomotive built by the Pennsylvania Railroad already referred to. This design is shown in outline in Fig. 6, on the opposite page, and the particulars are as follows :—

System	Single phase 25 cycles.
Voltage	11,000 volts.
Overall length	76 ft. 6½ in.
Total wheel base	63 ft. 11 in.
Driving wheel base	38 ft. 8 in.
Rigid wheel base	13 ft. 4 in.
Height from rail to top of cab	14 ft. 8 in.
Overall width	10 ft. 1 in.
Diameter of driving-wheels ...	72 in.
Diameter of pony wheels ...	36 in.
Total weight	223 tons.
Weight per driving axle ...	30 tons.
Starting tractive effort... ...	140,000 lb.
Normal working speed ...	20·6 m.p.h.

Many different designs of electric freight locomotives have been worked out on the Continent, and it is not possible to refer to all of them. Some have proved mechanically successful, others have been found unsatisfactory in one way or another. Many of the designs have been applied to one or two locomotives only, built mainly by way of experiment, and those which have been built in considerable numbers have been selected for mention only. There seems to be no signs, however, that any standard design of electric freight engine is being evolved on the Continent as representing the general consensus of opinion of Continental engineers.

6. The freight locomotives employed by the Swiss Federal Railways for the electrified line from Chiasso to Lucerne through the St. Gothard tunnel resemble in some respects the experimental locomotive built by the Pennsylvania Railroad. There are two pairs of motors, each pair being geared to a single jack-shaft by twin gearing. This jack-shaft is connected by cranks and side rods arranged on a special system to three driving axles. The complete locomotive consists of two trucks each having a guiding axle and three driving axles and a low superstructure containing the motors and some of the control apparatus, together with a central body carried on pivots by the two trucks, which contains the main transformer and the principal part of the electrical equipment. The general arrangement is shown in outline in Fig. 7. The particulars of the locomotive are as follows :—

Fig. 7. SWISS FEDERAL RAILWAYS. GOODS ELECTRIC LOCOMOTIVE. 2-6-0+0-6-2 TYPE.

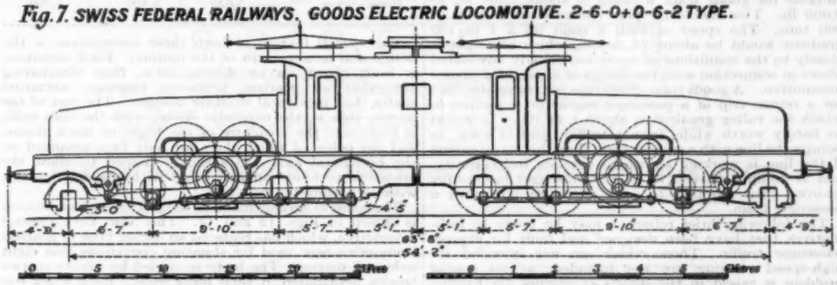
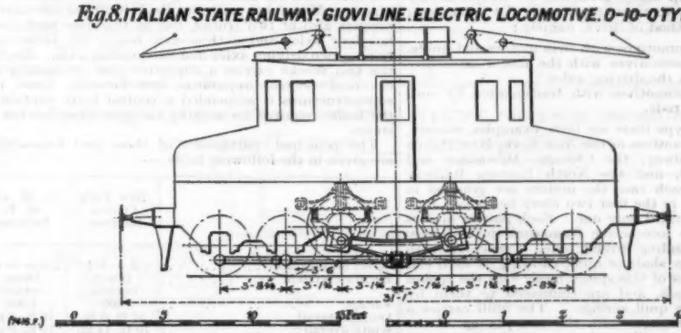


Fig. 8. ITALIAN STATE RAILWAY. GIOVI LINE. ELECTRIC LOCOMOTIVE. 0-10-0 TYPE.



Type	2-6 + 6-2.
Electrical system	Single phase 16⅔ frequency.
Voltage	15,000.
Length over buffers	63 ft. 8 in.
Total wheel base	54 ft. 2 in.
Fixed wheel base	15 ft. 5 in.
Diameter of driving wheels ...	4 ft. 5 in.
Number of motors	4.

	Continuous rating.	1½ hour rating.
H.P. of locomotive ...	1,700.	2,200.
Tractive effort of locomotive	28,800.	38,400.
Speed of locomotive ...	22 m.p.h.	21·5 m.p.h.
Maximum speed of locomotive		40 m.p.h.
Total weight of locomotive ...		128 tons.
Weight on drivers		104 tons.

The latest development of the electric locomotive in Switzerland is on the principle of the Quill type drive. Five of these have been built and running since September last, and four more are under construction in the Swiss locomotive works at Winterthur. These engines, of course, have no side-rods, and it will be interesting to see how they compare with the design which up to now has been universally adopted in Switzerland.

7. The Italian State Railways employ a ten-coupled electric locomotive for their freight traffic.

The following are the principal particulars of these locomotives :—

Type	0-10-0.
Electrical system	Three phase 15 to 16⅔ frequency.
Voltage	3,000 to 3,300.
Total weight	60 to 75 tons.
Number of motors	2.
Total power of motors ...	1,850 h.p.
Normal speeds	14 and 28 m.p.h.
Wheel diameter	42½ in.
Total wheel base	20 ft.

A considerable number of these have been built and put into service on the electrified lines in the North of Italy. The general arrangement of these locomotives is shown in outline drawing in Fig. 8. There are only two motors and these are coupled direct, that is, without any gearing, to the five driving axles by means of Scotch yokes and coupling-rods.

In addition to those mentioned above, other designs have been worked out in which the central feature is a single large motor, or a pair of large motors, mounted in the body of the locomotive, the drive being transmitted to several coupled axles by vertical or inclined connecting rods and one or two jack-shafts. These locomotives are not built on the bogie principle, the body being carried direct by the framework, which rests on the axle-boxes of the driving axles.

In comparing these various designs, the first point to be considered is whether the motors drive direct or through gearing. It must be remembered that the cost of the motors alone is something like 30 per cent. to 40 per cent. of the total cost of the locomotive. Any design, therefore, which leads to an unnecessarily large and costly motor is clearly at a disadvantage. For a given horse-power the lightest and cheapest motor is in general the motor which runs at the highest speed. For a freight locomotive a suitable motor speed can only be obtained by the use of gearing, unless the motor armature has a diameter about twice that of the driving-wheel. The latter alternative leads to a very unwieldy and expensive design. The majority of recent designs for freight locomotives make use of geared motors, whether they are geared direct to the driving axles or transmit their power through jack-shafts and coupling-rods. In the author's opinion, the employment of gearing which is now highly efficient and has a long life, is an essential feature of a satisfactory design.

The use of cranks and side-rods for a freight locomotive is clearly not a necessity, either for British railways where comparatively light trains have to be hauled, or in other countries, such as the United States, where the stronger drawgear makes it possible to deal with much heavier trains. The design of the Paulista locomotive already referred to, in which three-axle bogies are employed, each axle driven by its own motor, is one example of what can be done in the way of high-powered locomotives without having recourse to cranks and coupling-rods. Another example is the design adopted for the Chicago, Milwaukee and St. Paul Railroad.

The advocates of transmission by some form of coupling-rod contend that it reduces the proportion of dead weight on the track, as the whole weight of the motor is carried by springs, and that by grouping two, three or more axles together and connecting them to one or two motors, it enables larger and therefore, *pro rata*, cheaper motors to be employed than would be possible with individual drive.

The importance of keeping down the dead weight has been overestimated. It is obvious, of course, that the less the dead weight the easier is the locomotive on the track at the joints and crossings. It should be remembered, however, that the track has to withstand the shocks due to the passage of the whole train, not only of the locomotive. A full-sized train (on the British railways) will contain upwards of 100 axles without counting those of the locomotive, and it is difficult to believe that a little extra dead weight on the four axles of the locomotive alone will make any appreciable difference to the wear and tear of the track. It is much more likely that the life of the rails will be determined by the gradual wearing away of the head of the rail and in places by the reduction in area due to flange friction.

It must be remembered that on steam locomotives designed for freight service the dead weight on a pair of driving-wheels is as much as 4 tons, with a wheel diameter of about 4 ft. 6 in. (For steam passenger locomotives having 6 ft. 8 in. driving-wheels the dead weight may be as much as 6 tons.) For an electric freight locomotive, such as that built by the North Eastern Railway for the Shildon-Newport line, the dead weight with 48-in. wheels is not more than 4½ tons.

As to the advantage obtainable by the use of one or two large motors, instead of two or four smaller motors, while it is quite true that, other things being equal, the cost per horse-power falls as the size increases, the difference in favour of the larger motor is more than offset by the extra cost of the mechanical parts, due to the provision of the jack-shaft with its cranks and bearings, and the various coupling-rods with their bearings. In addition to this the framework of the bogie or truck carrying the axle and jack-shaft bearings must be made specially strong and massive to stand up to the reciprocating stresses inherent in this system of drive. The experience with the locomotives on the Norfolk and Western Railroad, where, in consequence of fractures, the bogie frames had practically to be redesigned and rebuilt, is a practical proof of this. Trouble of a similar nature has been experienced on other locomotives in which Scotch yokes are employed.

Quite apart from the increase in first cost of the locomotive, arising from the introduction of cranks, jack-shafts, Scotch yokes and coupling-rods, the question of maintenance cost is a matter of great importance. For satisfactory operation, it is essential that the jack-shaft bearings should be kept in proper adjustment and good condition, and the permissible wear of the brasses is small. If the locomotives have to come in frequently for adjustment of these bearings and for relining the brasses, &c., the cost of maintenance is considerably increased. Electric locomotives should be regarded as being fit for the road at all times, subject to proper arrangements being made for lubrication, attention to the brakes and periodical cleaning, inspection, and turning of tyres.

Taking all the foregoing points into account, the author is definitely of opinion that for the conditions which apply to British railways, the most suitable and satis-

factory arrangement for an electric freight locomotive is the double bogie design with two four-wheel bogies articulated together, each bogie containing two motors geared to the two axles without any form of coupling-rod transmission.

Where conditions differ from those on the British railways, that is, where the strength of the drawgear permits a greater drawbar pull, a similar arrangement, but with three axle-bogies, would seem to be the best, provided there is no objection to a rigid wheel-base of about 14 ft. As an alternative, if this wheel base is considered too long by reason of the curves on the track, the same general scheme of articulated bogies and individual geared motors can be adopted by designing the locomotive in one way or another with a sufficient number of four-wheel bogies. For example, if a short wheel-base is essential and the desired tractive effort makes it necessary to have 180 tons on the drivers, three double-bogie locomotives can be coupled together and operated as one.

Passenger Locomotives.—While it may be possible to go some way in the direction of standardising the design of locomotives intended for freight work, it is hardly possible to arrive at any definite conclusion in regard to the best design of locomotive for all sorts of passenger traffic. There are several reasons for this. In the first place, the weights of trains vary considerably, as also the speed and nature of the line, the gradients, &c. For example, on the Chicago, Milwaukee and St. Paul Railroad, the daily trains generally consist of 12 coaches, weighing on the average 70 tons to 75 tons each, and these have to be hauled up gradients as steep as 1 in 45. Partly on account of these gradients and partly because of the curvature of the line, the speed of these trains seldom rises much above 45 miles per hour, although where circumstances permit, higher speeds can be, and are, reached. On the British railways much lighter coaches are in use, and the average number of coaches in a train is probably not more than eight or nine. Speeds also vary, some expresses maintaining a speed of over 60 miles per hour for considerable distances, while local trains average about 30 miles per hour with frequent stops.

Secondly, many discussions have taken place as to the behaviour of locomotives of different designs when running at high speeds, such as those frequently attained on British railways. A locomotive of unsuitable design may start oscillating or "nosing," and the oscillations may reach such a degree as to injure the track or the locomotive. A number of special designs have been evolved with a view to the avoidance of these oscillations, but it cannot be said that there is yet any complete understanding as to the origin of the trouble, or agreement as to the best way of guarding against it. This point is discussed in more detail later.

Dealing first with the requirements for a standard passenger locomotive for the British railways, there are the following points to take into account:—

(1) Is it necessary that there should be more than one class of locomotive for all kinds of passenger traffic?

(2) If one class is sufficient, for what tractive effort and speed should the locomotive be designed, and can it be economically used for goods traffic when necessary?

In regard to the first question, it may seem at first sight obviously wrong to have only one class of locomotive for heavy fast expresses, and for light local trains. A locomotive for heavy express work is necessarily somewhat expensive, and it is clearly not economical to use it regularly for light duty. On the other hand, there is a good deal of advantage in keeping down as much as possible the number of classes of locomotive.

The answer to this question, at all events for the conditions on British railways, is to use the same engine for all expresses and fast trains running considerable distances without stopping, including all passenger trains which run beyond the limits of any electrified section, and to equip a sufficient number of trains as multiple unit trains without locomotives for the local passenger service. If this is done, the advantages of electrification can be obtained for both classes of passenger traffic economically and conveniently.

As a reply to the second question, some particulars may be given of the capacity of the passenger locomotive which has just been completed by the North Eastern Railway for experimental purposes. Full particulars of this engine are given below and the general design may be seen from the outline drawing in Fig. 12, on the opposite page. The conditions specified for the electrical equipment are as follows:—

(1) The adhesion weight of the locomotive will be not less than 17 tons per driving axle, and the complete electrical equipment shall be such that the motors can exert sufficient torque to skid the wheels without injury to themselves or to any part of the equipment.

(2) The motors shall be able to exert a total average tractive effort of 16,000 lb. at the tread of the driving-wheels when starting under normal conditions on level track.

(3) The capacity of the complete equipment shall be sufficient to enable the locomotive when coupled to a train weighing 450 tons to start from rest on a rising gradient of 1 in 78 and accelerate up to the first economical running speed without injury to any part of the equipment.

(4) The speed of the motors and gearing shall not exceed the limits of safety when the locomotive is travelling at 90 m.p.h.

(5) The locomotive shall be capable of hauling a train of 14 main line coaches weighing, with load, 450 tons, at not less than 65 m.p.h. on straight level track.

As will be seen from the schedule of particulars in the next table, there are three pairs of electric motors, each motor having a capacity of 300 h.p., so that the total capacity of the locomotive (one hour rating) is 1,800 h.p., measured at the tread of the wheels.

The use of three pairs of motors enables a wide range of speed to be obtained, as in the freight locomotive for the Paulista Railway mentioned above, by grouping the six motors—(1) all in series; (2) three in series, two in parallel; (3) two in series, three in parallel. With each grouping provision is made in the control equipment for regulating the speed by reducing the excitation of the motor fields. Thus there are for each grouping four different degrees of excitation, namely, full field, 18 per cent. reduction, 31 per cent. reduction, and 40 per cent. reduction. With this arrangement 12 different speeds are available for any particular value of the tractive effort. The performance curves, showing the relation between speed and tractive effort, as determined by work shop tests, are given in Fig. 9, on the opposite page. From these it will be seen that the maximum tractive effort corresponding to a speed of 65 m.p.h. is 8,400 lb. or 3¾ tons. The tractive resistance of the locomotive alone at this speed, including that due to windage, should not be more than about 1,600 lb. The drawbar pull would therefore be about 6,800 lb., equivalent to about 15 lb. per ton for a 450-ton train. This should be ample to maintain a speed of 65 m.p.h. on the level under any ordinary conditions of weather.

Referring again to the performance curves in Fig. 9, it will be seen that a tractive effort of 8,000 lb. to 10,000 lb. can be obtained at a speed of 31 m.p.h. to 34 m.p.h. Allowing, say, 900 lb. for the tractive resistance of the locomotive alone, the drawbar pull available at a speed suitable for goods train working is about 7,000 lb. to 9,000 lb. This should be quite sufficient for a train of 600 tons. The speed of such a train up a 1 in 100 gradient would be about 24 m.p.h., which corresponds closely to the conditions of operation already advocated above in connection with the design of a standard freight locomotive. A goods train of 600 tons is a reasonable load for a return trip of a passenger engine on a section in which the ruling gradient is about 1 in 100. It would be hardly worth while, from a traffic point of view, to occupy the line with a smaller train than this, at all events if the line is working anywhere near its full capacity, and it would be better to let the passenger locomotive lie-over until required to work a return trip with a passenger train.

The following brief reference may be made to locomotives that have been designed and built for express passenger traffic. Those which are not intended for high-speed running are not included, as no special problem is raised in the design of engines for hauling passenger trains up steep gradients at comparatively low speed. Three distinct types may be mentioned differing in the method of drive, namely:—

(*a*) Geared locomotives with twin motors and quills.
(*b*) Gearless locomotives with the motor armatures built on the driving axles.
(*c*) Gearless locomotives with transmission by connecting rods.

(*a*) Of the first type there are three examples, namely, the passenger locomotives of the New York, New Haven and Hartford Railway, the Chicago, Milwaukee and St. Paul Railroad, and the North Eastern Railway respectively. In each case the motors are grouped in sets of three pairs, in the first two there being two such groups and in the third only one. Each pair of motors is mounted in the locomotive framework immediately above the corresponding driving axle. Concentric with this axle is a hollow shaft or quill, carrying at each end a spider. The arms of this spider mesh with the spokes of the driving-wheels, and are connected to them by springs called "the quill springs." The quill carries a gear-wheel which engages with the two pinions of the pair of motors. The quill runs in "suspension" bearings which form part of the motor frame, and the distance between the gear centres is thus definitely maintained. This arrangement allows a pair of motors to be geared to a single driving axle through a flexible connection, allowing the axle to move up and down on the axle-box guides without transmitting the movement to the motors. The dead weight on the track is therefore reduced to the minimum. The general arrangement of each of these three locomotives will be seen from the outline drawings in Figs. 10, 11 and 12, on the opposite page, and the principal particulars are given in the table which follows.

Each of these locomotives is equipped with a small boiler specially provided for producing the steam necessary for the heating of the passenger coaches. On the first two locomotives this boiler is fired by oil fuel. On the locomotive built by the North Eastern Railway a specially designed boiler has been installed in which steam is produced electrically. So far as is known, this is the first electric boiler used for this purpose in which the heating elements are designed for direct current at a pressure of 1,500 volts. Electric boilers have been in service for some years on lines electrified on the alternating current system, where, of course, it is a simple matter to provide a small step-down transformer so that the necessary electrical energy may be supplied to the boiler at a suitable low pressure. To do the same thing on a 1,500 volt d.c. circuit would require the provision in the locomotive of a motor generator of about 300 kw. capacity. Such a motor generator would, of course, be an unwelcome addition to the electrical equipment of the locomotive. For this reason there is a definite advantage in the use of a boiler which is suitable for the line pressure of 1,500 volts.

The boiler is of the fire-tube type, each tube containing a heating element consisting of a tube of quartz in the interior of which there is a spiral of high resistance wire. The boiler contains in all 144 of these elements, and switchgear is provided so that the number of elements in circuit can be reduced as desired when the full output is not required from the boiler. The maximum output is about 1,000 lb. of steam per hour at a pressure of 120 lb. per square inch.

(*b*) Of the second type there are two well-known examples, namely, the passenger locomotives on the New York Central Railroad and the Chicago, Milwaukee and St. Paul Railroad.

——	N.Y., N.H. and H.	C., M. and St. P.	N.E.R.
Wheel arrangement	2-6-2+2-6-2	4-6-2+2-6-4	4-6-4
Electrical system	Direct current and single-phase	Direct current	Direct current
Voltage	600and11,000	3,000	1,500
Length overall	69 ft. 0 in.	88 ft. 7 in.	53 ft. 6 in.
Width overall	10 ft. 2 in.	11 ft. 0½ in.	8 ft. 10 in.
Height, pantograph locked down	14 ft. 2 in.	17 ft. 0 in.	13 ft. 0½ in.
Driving wheel diam.	63 in.	68 in.	80 in.
Pony wheel diameter	36 in.	36 in.	43½ in.
Rigid wheel base	14 ft. 3 in.	16 ft. 9 in.	16 ft. 0 in.
Weight of locomotive	161 tons.	245 tons	102 tons
Weight per driving axle	18 tons	25 tons	18 tons 10 cwt.
One hour rating—			
Tractive effort	21,000 lb.	66,000 lb.	15,900 lb.
Speed	45·6 m.p.h.	23·8 m.p.h.	43 m.p.h.
Horse-power	2,550	4,200	1,800
Continuous rating—			
Tractive effort	14,500 lb.	40,800 lb.	9,480 lb.
Speed	52·5 m.p.h.	30·4 m.p.h.	51·5 m.p.h.
Horse-power	2,025	3,400	1,300

The special feature of both these locomotives is the design and arrangement of the motors. Each armature is built direct on its driving axle, thus eliminating altogether all gearing, armature bearings, armature shafts, &c., incidental to other designs. The rest of the motor, that is, the magnetic circuit with the field coils, is built into the structure of the bogie or truck frame, and the poles, of which there are only two, arranged on the horizontal axis, are specially shaped to allow the armature to move up and down with the driving axle without fouling the pole-tips.

The general arrangement of each of these locomotives is shown in Figs. 13 and 14. The New York Central locomotive, which has replaced an earlier type of gearless locomotive now used for shunting operations, has eight axles, all driven. The body is carried by pivots on two trucks, articulated at their inner ends. Each truck has two fixed driving axles and a four-wheeled bogie. The Chicago, Milwaukee and St. Paul Railroad locomotive consists also of two trucks, but in this case each truck has four axles and a three-axle bogie, the latter containing two driving axles and one guiding axle. Each of the two trucks carries a superstructure containing the electrical control apparatus and between these two superstructures is suspended a central body containing the boiler required for heating the passenger coaches by steam.

The principal particulars of these two locomotives are given in the following table:—

——	New York Central Railroad.	C., M. and St. P. Railroad.
Wheel arrangement	4-4-4-4	2-4-8-8-4-2
Electrical system	Direct current	Direct current
Voltage	600	3,000
Length overall	57 ft. 0 in.	76 ft. 0 in.
Width overall	10 ft. 1½ in.	10 ft. 0 in.
Height, pantograph locked down	14 ft. 6 in.	16 ft. 8 in.
Driving wheel diameter	36 in.	44 in.
Pony wheel diameter	None	36 in.
Rigid wheel base	6 ft. 6 in.	13 ft. 9 in.
Total wheel base	46 ft. 5 in.	67 ft. 0 in.
Weight of locomotive	118 tons	236 tons
Weight per driving axle	14·75 tons	17 tons
One hour rating—		
Tractive effort	20,000 lb.	46,000 lb.
Speed	49 m.p.h.	27·5 m.p.h.
Horse-power	2,600	3,480
Continuous rating—		
Tractive effort	14,000 lb.	32,000 lb.
Speed	58·3 m.p.h.	37·8 m.p.h.
Horse-power	2,000	3,200

(*c*) Of the third type, namely, that in which the torque is transmitted to the driving-axles by means of cranks and coupling rods, only three will be mentioned, namely, the Pennsylvania Railroad locomotives, built in 1910, the passenger locomotive built for the Dessau-Bitterfield section of the Prussian State Railways in 1912, and the locomotives recently built by the Paris-Orleans Railway for the line Paris-Quai d'Orsay to Juvisy. A good many other locomotives have been built in the last 10 or 12 years of this general type, which are used for hauling passenger trains, such as those on the Italian State Railways, the Loetschberg Railway, the Swiss Federal Railways, and elsewhere, but in no case is the average speed over considerable distances above or equal to 60 m.p.h.

The general arrangement of each of the three locomotives mentioned above is shown in the outline drawings, Figs. 15, 16 and 17 (page 800). The Pennsylvania locomotive consists of two 4-4-0 engines short-coupled back to back, each engine containing a single motor driving by means of inclined coupling-rods, a jack-shaft and horizontal rods.

The Dessau-Bitterfield locomotive has a wheel arrangement 4-4-2, and contains a single motor driving by means of vertical rods, a jack-shaft and horizontal rods.

The Paris—Orleans locomotive has a wheel arrangement 2-8-2, and contains two motors which drive through inclined and horizontal coupling-rods.

The principal particulars of the locomotives of this type are given in the following table:—

—	Pennsylvania.	Dessau-Bitterfeld.	Paris-Orleans.
Wheel arrangement	4-4-0+0-4-4	4-4-2	2-8-2
Electrical system ..	Direct current	Single-phase 15-cycles	Direct current
Voltage	600	10,000	600
Length overall	64 ft. 11 in.	41 ft. 0 in.	40 ft. 0 in.
Width overall ..	10 ft. 6 in.	9 ft. 11 in.	10 ft. 2 in.
Driving wheel diam.	72 in.	63 in.	59 in.
Pony wheel diameter	36 in.	39⅜ in.	33½ in.
Rigid wheel base ..	7 ft. 2 in.	—	5 ft. 9 in.
Weight of locomotive	140 tons	72·25 tons	85·6 tons
Weight per driving axle	21·75 tons	15·125 tons	16·8 tons
One hour rating—			
Tractive effort ..	20,150	12,000	—
Speed	32·6	31·3	—
Horse-power ..	1,750	1,000	2,000

It may be of interest to compare the performance curves of the locomotives described above. For this purpose the author has put together in one diagram, Fig. 18, (page 800) the curves of tractive effort against speed for the maximum condition of output for all the locomotives of which particulars have been already given, with the exception of the quill drive locomotive for the New York, New Haven and Hartford Railroad, of which the author has been unable to obtain the performance curves.

This comparison will bring out the fact that these engines differ considerably in their capabilities in respect of both the load to be hauled and the speed at which the trains will travel.

For example, the quill-drive locomotive employed for passenger work on the Chicago, Milwaukee and St. Paul Railroad has a tractive effort of only 7,200 lb. at a speed of 65 miles per hour as compared with 8,400 lb. at the same speed for the North Eastern Railway locomotive, in spite of the fact that the latter has only six 300-h.p. motors, whereas the former has 12 motors each of 350 h.p. On the other hand, the Chicago, Milwaukee and St. Paul locomotive, having approximately three times as much weight on the driving-wheels as the North Eastern Railway locomotive, is able to exert a far greater tractive effort at low speeds, and in fact is intended principally for hauling trains of about 800 tons up gradients as steep as 1 in 45.

A comparison of these various curves shows that the North Eastern Railway locomotive is well adapted to deal with the loads for which it is intended, and at the speeds at which it is desired to run, without being heavier or more powerful than is necessary for this duty.

While it is clear, therefore, that all these locomotives are not equally well suited to meet the requirements of express passenger traffic on the British railways, it does not follow that a suitable locomotive cannot be designed embodying any one of the systems of drive peculiar to the three general types mentioned above. Whatever the merits or demerits of type (a) the particulars already given of the locomotive just completed by the North Eastern Railway show that the tractive effort and speed characteristics desired can be obtained without difficulty. Equally with type (b) the same characteristics can be obtained by proper design of the motors and the diameter of the driving-wheels. The arrangement of drive lends itself well to high-speed running. The higher the speed the greater the periphery velocity of the motor armature mounted direct on the driving-axle, and consequently better use is made of the active material of the motor. As an illustration of this point it may be mentioned that about the time when the order for the electrical equipment for the North Eastern Railway passenger locomotive was placed with the Metropolitan-Vickers Company, a proposal was submitted by the General Electric Company, U.S.A., for a locomotive with direct drive gearless motors to conform to the same specification. For various reasons it was decided to postpone the building of this second engine, but the particulars of the design may be of interest, and are given under the general arrangement shown in the outline drawing, Fig. 19, on page 800.

Fig. 9. TRACTIVE EFFORT-SPEED CURVES FOR 4-6-4 ELECTRIC PASSENGER LOCOMOTIVE, NORTH EASTERN RY.

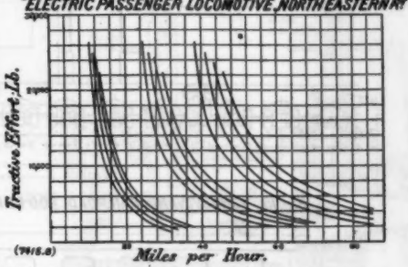


Fig. 10. NEW YORK, NEW HAVEN AND HARTFORD RAILROAD. QUILL DRIVE ELECTRIC LOCOMOTIVE. 2-6-2+2-6-2 TYPE.

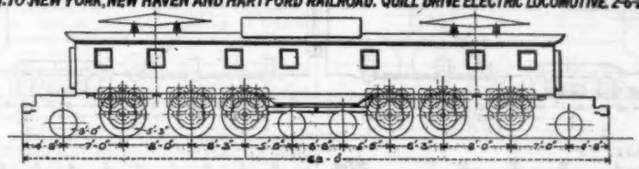


Fig. 11. CHICAGO, MILWAUKEE AND ST. PAUL RAILROAD. QUILL DRIVE ELECTRIC LOCOMOTIVE. 4-6-2+2-6-4 TYPE.

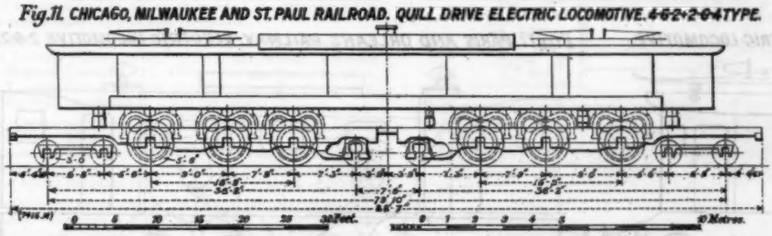


Fig. 12. NORTH EASTERN RAILWAY. HIGH-SPEED ELECTRIC PASSENGER LOCOMOTIVE. 4-6-4 TYPE.

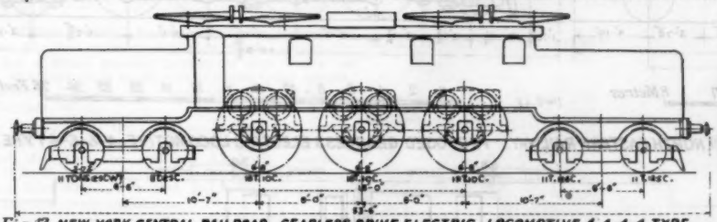
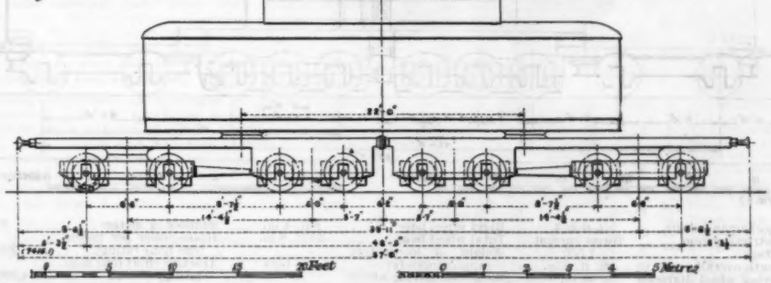


Fig. 13. NEW YORK CENTRAL RAILROAD. GEARLESS DRIVE ELECTRIC LOCOMOTIVE. 4-4-4-4-4 TYPE.



While it is clear, therefore, that all these locomotives are not equally well suited to meet the requirements of express passenger traffic on the British railways, it does not follow that a suitable locomotive cannot be designed embodying any one of the systems of drive peculiar to the three general types mentioned above. Whatever the merits or demerits of type (a) the particulars already given of the locomotive just completed by the North Eastern Railway show that the tractive effort and speed characteristics desired can be obtained without difficulty. Equally with type (b) the same characteristics can be obtained by proper design of the motors and the diameter of the driving-wheels. The arrangement of drive lends itself well to high-speed running. The higher the speed the greater the periphery velocity of the motor armature mounted direct on the driving-axle, and consequently better use is made of the active material of the motor. As an illustration of this point it may be mentioned that about the time when the order for the electrical equipment for the North Eastern Railway passenger locomotive was placed with the Metropolitan-Vickers Company, a proposal was submitted by the General Electric Company, U.S.A., for a locomotive with direct drive gearless motors to conform to the same specification. For various reasons it was decided to postpone the building of this second engine, but the particulars of the design may be of interest, and are given under the general arrangement shown in the outline drawing, Fig. 19, on page 800.

So far as type (c) is concerned, namely, the design in which coupled wheels are driven by cranks and rods, it is obviously a simple matter to provide for any desired tractive effort-speed characteristic by a proper selection of the diameter of the driving-wheels and a suitable design of the driving motor or motors. There need be no gearing, and there is therefore no limitation in respect of gear-velocity to be taken into account. If a high speed is desired it is a simple matter to increase the wheel-diameter, keeping the crank radius the same.

It is clear, therefore, that so far as the system of drive is concerned any one of the three general schemes referred to above can be selected. Apart from this, however, there are two questions to consider, namely—

(1) Is there any outstanding advantage in any one of the three types over the others?

(2) What should be the general mechanical arrangement of an express passenger locomotive to suit the requirements of British railways?

In view of the small experience which has so far been acquired of working express passenger traffic by electric locomotives it is hardly possible yet to come to any conclusion as to whether one or other of the three types mentioned above is definitely to be preferred to the others. One can safely say that as regards the first two types, namely, the quill drive and the gearless motor, each has its own good points.

The advantages of the quill drive may be stated as follows:—The dead weight on the track is reduced to the minimum as the motor is entirely spring-borne, the motors are geared and therefore can be designed for a satisfactory peripheral speed, thus enabling the fullest use to be made of the active material, and finally the centre of gravity of the complete locomotive is reasonably high, owing to the use of driving-wheels of large diameter and the mounting of the motors above the centres of the driving axles. For example, on the 4-6-4 locomotive, built by the North Eastern Railway, the dead weight per axle consists only of the two driving-wheels and the axle, which weigh 4 tons 15 cwt., and as the diameter of the driving-wheels is 6 ft. 8 in. the effect of this dead weight on the track will be much less than in another case, where the weight might be the same and the diameter of the driving-wheels, say, 4 ft. On the same locomotive the peripheral velocity of the armatures corresponding to a locomotive speed of 75 miles per hour, is 5,500 ft. per minute, and the centre of gravity of the complete locomotive is about 4 ft. 10 in. above rail level.

On the other hand, the advantages of the gearless locomotive are as follows:—The electrical equipment is extremely simple, there being no gearing, no special armature shafts, armature bearings, suspension bearings, &c. There is also no necessity for the expensive quill with the spiders and quill-springs. These points tend to compensate for the higher cost of the motor itself which, by reason of its low peripheral speed, is comparatively expensive. It is also claimed that the simplicity of the electrical arrangements leads to a lower cost of maintenance than is possible with any form of geared motor, combined with quill drive.

For example, in the gearless locomotive, which the General Electric Company proposed to supply to the North Eastern Railway, the dead weight per axle with driving-wheels of only 42 in. would be 3 tons, and the peripheral velocity of the armature at a locomotive speed of 75 miles per hour would be only 3,540 ft. per minute.

In regard to the third type, namely, that in which the power is transmitted to the driving wheels by means of cranks and coupling-rods, the view has already been expressed in reference to the freight locomotives that there are inherent disadvantages in the use of coupling-rods from which other forms of transmission are free. For express passenger locomotives it may be claimed that owing to the higher speed it is easier to run the armatures at the desired high peripheral velocity without the use of gearing. This, however, can only be done by the use of comparatively small driving-wheels which with their cranks, must revolve at a speed considerably above that in common practice with steam locomotives.

As the revolving masses of the cranks, coupling-rods, &c., cannot be exactly counter-balanced, this high-speed is liable to give rise to considerable vertical oscillations. It may be that by careful design a suitable locomotive could be constructed on this principle which would run at the speeds required for express passenger traffic on British railways, but even if this were successful there is still the drawback that the maintenance cost of the various crank-pin bearings, jack-shaft bearings, &c., would be unduly high. In the author's opinion, therefore, the choice at present lies between the first two types, namely, the quill-drive and the gearless locomotive, and further experience is necessary before any decisive opinion can be expressed as to which of these two types is to be preferred.

The question as to the most satisfactory mechanical arrangement of an express passenger locomotive for the British railways must be considered in reference to the discussion, which has been occupying the attention of railway engineers for some time now, in regard to the possibility of oscillations or nosing of the locomotive when running at high speeds. Experience in the United States with various designs of locomotives, we are assured, has proved that an electric locomotive cannot be expected to travel satisfactory at such speeds as we are considering, say, 70 m.p.h. to 75 m.p.h., if the wheel arrangement is symmetrical. For example, a 4-6-2

locomotive might perhaps be satisfactory, whereas a 4-6-4 locomotive would be unsatisfactory. This, of course, is an important point if one bears in mind that one of the advantages of electric working is that there is no necessity for turning the locomotive at the end of each journey. This is only possible if the locomotive can run equally well in both directions. For such speeds as we are considering it might be quite satisfactory to run a 4-6-2 locomotive with the bogie leading, but not with the bogie trailing, and therefore it is desirable that in whichever direction the locomotive runs there should be a bogie leading. Engineers in the United States who have considered this matter, advocate a construction which, while not symmetrical, does provide for a bogie at each end of the locomotive. For this purpose they recommend one or other of the various designs which are based on the articulation of two locomotives back to back. Thus, for example, they have suggested at one time and another locomotives having wheel arrangements 4-6-0 + 0-6-4, with the idea that while the locomotive, considered as a whole, is symmetrical, each part of the locomotive is unsymmetrical, and that therefore each part will run satisfactorily without setting up violent oscillations of the locomotive as a whole.

It is difficult to find any satisfactory explanation of the difficulties which have been experienced in the United States in this direction, especially in view of the fact that there are on the British and Continental railways already a fair number of symmetrical locomotives which are capable of running at high speeds. Before coming to any decision to build the 4-6-4 electric locomotive for the North Eastern Railway, the author inquired as to the behaviour of the steam locomotives possessed by the Chemins de Fer du Nord of the 4-6-4 type, and Mr. Briville, the chief engineer of the company, kindly wrote saying that experience showed that their locomotives of this design were capable of attaining a maximum speed of 120 km. per hour (75 m.p.h.) without experiencing any difficulty in regard to oscillations.

On the London, Brighton and South Coast Railway they have for some years run engines of the symmetrical type (4-6-4), and Mr. Billinton states that he has made oscillation tests which have shown satisfactory results.

The North Eastern Railway have a 4-4-4 symmetrical type which has run up to 70 m.p.h. without finding any ill effects. In view of this, it is evident that there must be some cause which gives rise to violent oscillations on symmetrical electric locomotives when running in the United States which are absent when symmetrical steam locomotives are run in Europe. It may be argued that although the wheel arrangement of the steam locomotives mentioned is strictly symmetrical, the distribution of the weight in the superstructure of the steam locomotive is unsymmetrical. The author does not consider, however, that this can make any substantial difference in the behaviour of the locomotive. It appears to him that the oscillations can only arise from the fact that there is a periodic disturbance tending to set up horizontal oscillations, the frequency of this disturbance being the same as the natural frequency of the locomotive in oscillating in a horizontal plane. As soon as these two frequencies coincide, the oscillations tend to increase until they become dangerous. This natural frequency of the locomotive, however, while it may possibly be slightly changed by an unsymmetrical distribution of the masses of the locomotive superstructure, cannot certainly be eliminated, so that any such distribution might possibly affect the speed at which these violent oscillations occur without in any way eliminating the tendency to oscillate.

There is no doubt a good deal yet to be learned about the behaviour of electric locomotives of a symmetrical arrangement when running at high speeds, but he ventures to suggest that one possible cause of the trouble experienced in the United States and from which the European railways seem to be free, is that on practically all the railways in the United States the rail joints are staggered, whereas on the British railways, and he understands, on the French railways also, the rail-joints are opposite to each other. The staggering of the joints in the United States must set up a periodic disturbing force both horizontal and vertical. The frequency of this disturbance will depend entirely upon the speed at which the locomotive travels. If the design of the locomotive is such that its own natural frequency corresponds to the frequency of this disturbance at a fairly high speed, then the oscillations set up will tend to become violent. With rail-joints opposite each other as they are on the British and French railways, the same periodic disturbing force cannot be set up, and any oscillation of the locomotive which may arise from any local

Fig. 14. CHICAGO, MILWAUKEE AND ST. PAUL RAILROAD. GEARLESS ELECTRIC LOCOMOTIVE. 2-8-8+8-8-2 TYPE.

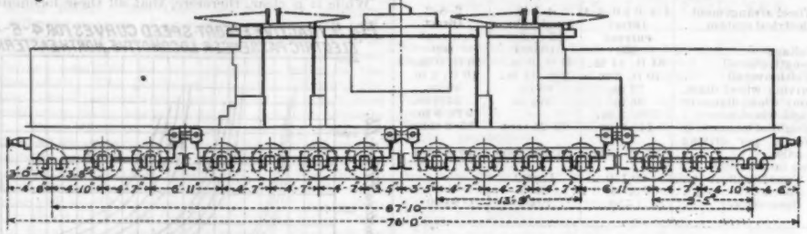


Fig. 15. PENNSYLVANIA RAILROAD. ROD DRIVE ELECTRIC LOCOMOTIVE. 4-4-0+0-4-4 TYPE.

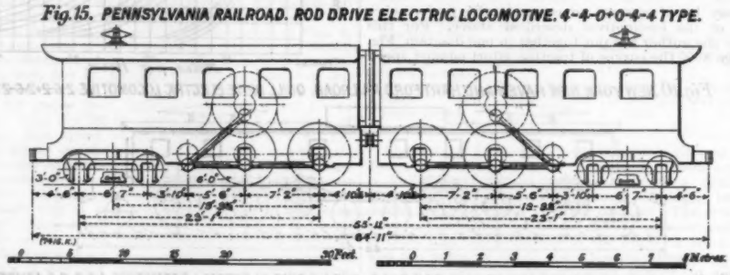


Fig. 16. PRUSSIAN STATE RAILWAYS. PASSENGER ELECTRIC LOCOMOTIVE. 2-4-4 TYPE.

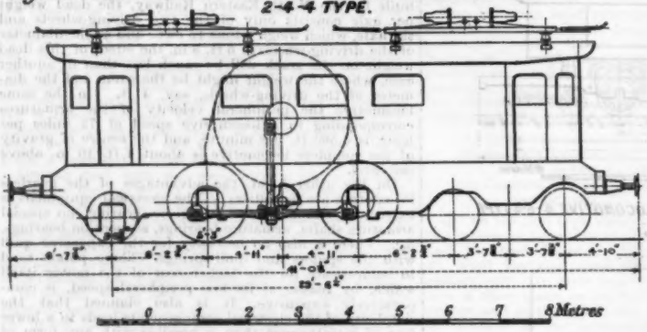


Fig. 17. PARIS AND ORLEANS RAILWAY. ELECTRIC LOCOMOTIVE. 2-8-2 TYPE.

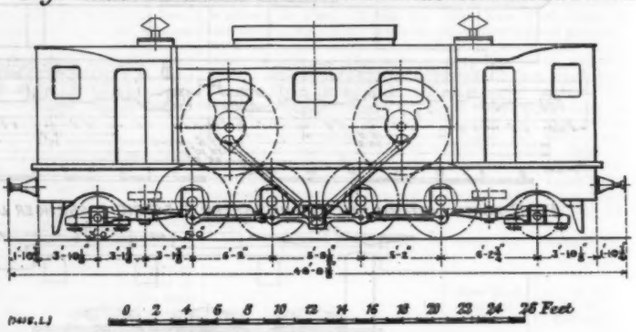


Fig. 18. TRACTIVE EFFORT-SPEED CURVES OF ELECTRIC PASSENGER LOCOMOTIVES.

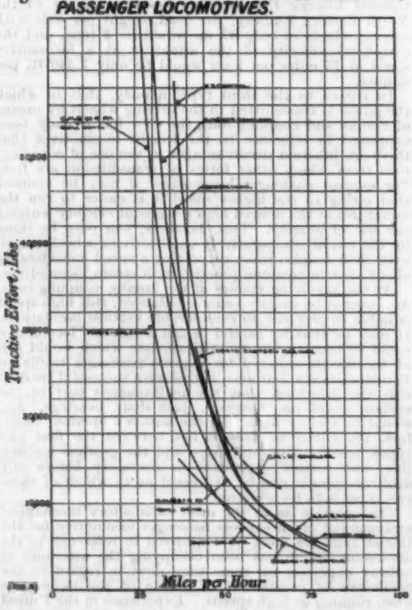
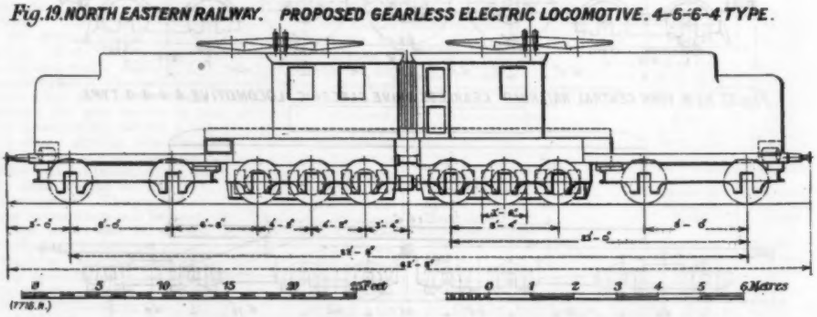


Fig. 19. NORTH EASTERN RAILWAY. PROPOSED GEARLESS ELECTRIC LOCOMOTIVE. 4-6-6-4 TYPE.



Wheel arrangement ..	4-6-6-4	Rigid wheel base ..	8 ft. 4 in.	Number of motors ..	6
Electrical system ..	Direct current	Total wheel base ..	52 ft. 8 in.	Horse-power per motor (one hour rating) ..	300
Voltage	1,500	Weight of locomotive (approximately) ..	105 tons	Tractive effort (one hour rating)	14,000 lb.
Length overall	62 ft. 8 in.	Weight on driving wheels (approximately) ..	67 tons	Speed (one hour rating)	47 m.p.h.
Driving wheel diameter	42 in.				
Bogie wheel diameter ..	42 in.				

cause would tend to die out immediately after it has started. The whole question, however, is one of considerable difficulty, but it is hoped that after extended trials of the 4-6-4 locomotive on the North Eastern Railway he will be in a position to express a more definite opinion.

Without going too much into details of design, the author has endeavoured to point out the principal features of the various designs now in use, and to show reasons for the conclusion he has come to in recommending certain designs as being most suitable for the work on British railways. It is important, however, the types should be as few as possible from an economic point of view, and he considers that it is possible to confine these to within five separate designs.

In conclusion, the author wishes to take this opportunity of thanking Mr. F. Lydall for the very valuable assistance he has given him in connection with this paper.

CATALOGUES.

Porthole Frames.—A catalogue of port holes, frames and glazing, in several types, is to hand from the Ateliers and Chantiers de la Loire Company, Nantes, France.

Welding.—An illustrated and fully descriptive booklet on the welding of tramway and other rails is to hand from Thermit, Limited, 155, Church-road, Battersea, London, S.W. 11.

Pumps.—The Pulsometer Engineering Company, Limited, Reading, send a copy of a booklet of tables, formulae and general data which those in charge of pumps will find very useful.

Graphite Lubrication.—A small booklet on graphited oil, containing much useful matter on lubrication has been issued by Messrs. E. G. Acheson, Limited, 40, Wood-street, London, S.W. 1.

Coal Mining.—Messrs. Mavor and Coulson, Limited, 47, Broad-street, Mile End, Glasgow, send the 11th issue, dated June, of their little monthly journal compiled to supply information to those interested in extending the use of mechanical appliances in mines.

Machine Tools.—We have received the May-June issue of the journal issued by the Associated British Machine Tool Makers Limited, 17, Grosvenor-gardens, London, S.W. 1, containing several articles describing the construction and operation of machine tools.

Air Compressors.—A catalogue from Messrs. Bellisa and Morcom, Limited, Birmingham, shows a type of air compressor which they have made standard with capacities up to 3,000 cub. ft. of free air per minute, any larger volume being supplied by two or more of these machines.

Reinforced Concrete Construction.—A 60-page illustrated catalogue describes a quite impressive series of marine and harbour construction works in reinforced concrete carried out in recent years by Messrs. Christiani and Nielsen, whose London office is at 74, Victoria-street, London, S.W. 1.

Electric Water Heater.—A domestic water heater for connection to the ordinary lighting wires, especially suitable for a small regular supply of hot water, is described in a four page catalogue received from Messrs. George Nobbs, Limited, 89, Cleveland-street, Fitzroy-square, London, W. 1.

Testing Transformer Oil.—An equipment for testing the oil for use in oil-immersed electrical apparatus, made by Messrs. Johnson and Phillips, Limited, Charlton, London, S.E. 7, is described in a special catalogue to hand from that firm. The test is for the purpose of ensuring freedom from moisture.

Roller Bearings.—Two catalogues of their flexible spiral roller bearings have come from Messrs. Hyatt, Limited, 56, Victoria-street, London, S.W. 1. One deals with the application of the bearings to motor vehicles and the other with industrial applications. In both there are very full lists of stock sizes with all dimensions and load capacities.

Grinding Machines.—A catalogue of plain, universal and internal grinding machines with a full range of accessories for a variety of works has reached us from Messrs. A. A. Jones and Shipman, Limited, Leicester. These machines are made for the most accurate work, and are fitted with every convenience for rapid operation. The catalogue should be considered carefully in comparison with those describing foreign-made machines.

Shop Fitting.—A catalogue of 48 quarto pages giving particulars of rolling shutters, shop fronts, blinds, extending steel gates, swing signs, wood and metal letters, and many similar manufactures has come to hand from Messrs. S. W. Francis and Co., Limited, 70, Grays Inn-road, London, W.C. 1. The firm supplies materials or finished articles, and also undertakes complete installation.

Coolers.—A carefully designed and substantially built cooling apparatus especially suitable for closed circuits of engine-lubricating oil, cylinder-cooling water, &c., is described in a catalogue received from the Griscom-Russell Company, 90, West-street, New York. The cooling water is run through straight tubes and the liquid to be cooled circulates in a helical path between the shell and the tubes.

Condensing Plant.—The rotary jet condenser and rotary jet vacuum pump made by the Rees-Roturbo Manufacturing Company, Limited, Wolverhampton, are described in a special catalogue issued by that firm. The illustrations in the catalogue include the general lay-out for installations for turbines, reciprocating engines and vacuum pans for sugar manufacture, all of which are large scale equipments. Much relevant technical information is given in tables and diagrams.

FEED-WATER HEATERS FOR LOCOMOTIVES.*

By Professeur Edouard Sauvage, of Paris, Member.

Among the various improvements on the locomotive with a view to economy of fuel, one of the simplest consists in heating the feed-water by waste heat. For exhaust steam it is quite an easy matter to heat the water close up to 100 deg. C. Almost since the commencement of the locomotive, feed-water heaters on that principle have been used. Still, despite numerous applications and frequent trials of various systems, the use of this apparatus was quite limited, and nearly all of them, after a more or less prolonged service, entirely disappeared.

Fig. 1. TYPE F LOCOMOTIVE EXHAUST STEAM INJECTOR (METCALFE).

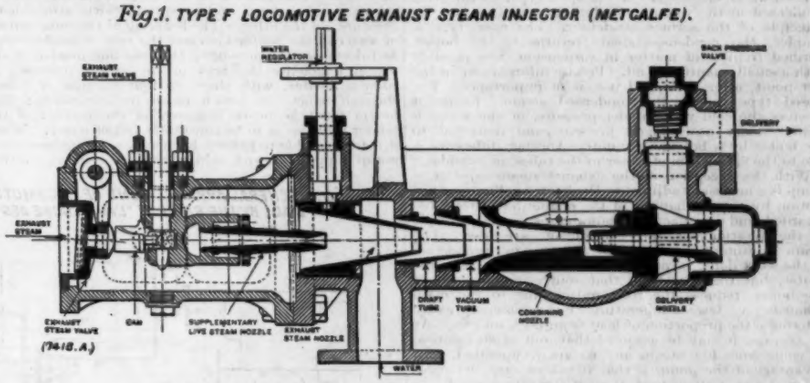
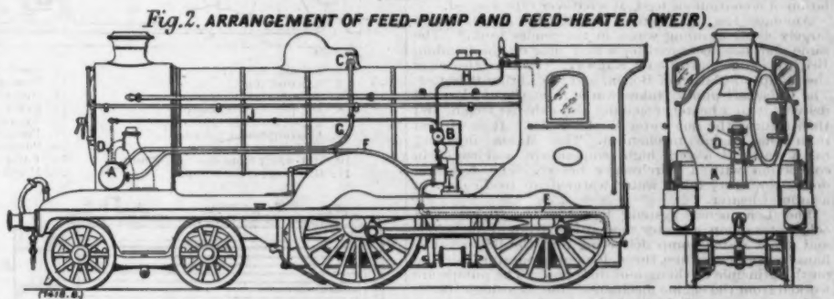
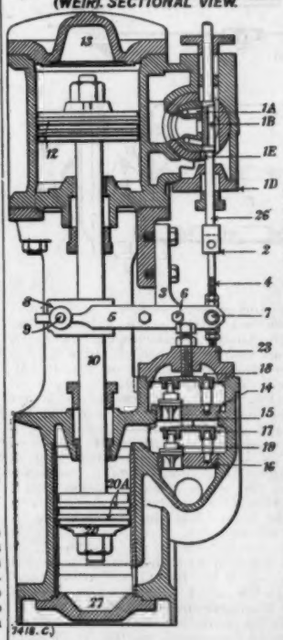


Fig. 2. ARRANGEMENT OF FEED-PUMP AND FEED-HEATER (WEIR).



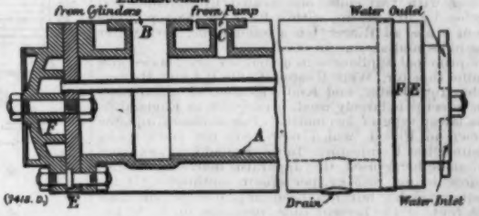
A. Heater.
B. Pump.
C. Spray-valve.
D. Exhaust steam to heater.
E. Pump suction.
F. Pump discharge.
G. Discharge from heater.
H. Pump steam.
J. Pump exhaust.

Fig. 3. LOCOMOTIVE FEED-PUMP (WEIR). SECTIONAL VIEW.



1A. Main slide-valve.
1B. Auxiliary slide-valve.
1D. Bottom cover of valve-chest.
1E. Liner for piston valve-chest.
2. Double joint.
6. Front stay.
4. Bottom spindle.
5. Valve-gear levers.
6. Front stay bush.
7. Ball crosshead.
8. Main crosshead.
9. Crosshead-pin.
10. Piston rod.
12. Piston rings.
13. Cylinder cover.
14. Discharge - valve seat.
15. Discharge - valve seat ring.
16. Suction-valve seat
17. Suction - valve guard.
18. Discharge - valve guard.
19. Water-valves.
20. Bucket.
20A. Bucket-rings.
23. Valve-chest cover.
26. Auxiliary valve-spindle.
27. Pump bottom cover.

Fig. 4. LOCOMOTIVE FEED-HEATER (WEIR).



that purpose utilisation of the hot gases discharged up the chimney does not appear practical, on account of the weight and bulk of the economisers, although in exceptional cases this system has been adopted.† But with Nevertheless, in recent years, the feeling of locomotive engineers towards heaters seems to have been changed, and several important railway companies have given serious attention to the question. New apparatus has been carefully designed, applications become every day more numerous, and there are now indications of their adoption on an extended scale.*

Utilisation of exhaust steam is, in principle, a very simple process, and its efficiency is easy to calculate. For instance, on a locomotive, with an effective steam-pressure of 14 kg. per square centimetre (200 lb. per square inch), and superheated to 340 deg. C. (644 deg. F.), the temperature of the feed-water being 15 deg. C. (59 deg. F.), the production of 1 kg. (2·205 lb.) of steam requires 723 calories.† By heating the water from 15 deg. C. (59 deg. F.) to 95 deg. C. (203 deg. F.), that is, using 80 calories, of which it may be assumed that three-fourths are given by the exhaust steam, 60 calories out of 723 are recuperated, that is, 8·3 per cent., and the proportion is greater when the steam is not superheated. The service of the engine remaining the same as before feed-water heating, the fuel economy may be in excess of that figure, owing to the increased utilisation of heat in the boiler, due to a reduced production, the temperature of gases rejected in the smoke-box being lower and the quantity of cinders smaller. On the other hand, with the same rate of combustion, 9 per cent. more steam will be produced, 1 kg. of steam requiring 663 calories instead of 723. This calculation assumes that all water passes through the heater, and does not apply to special cases where the nature of the service requires the frequent use of the ordinary injector.

The fear, sometimes expressed, that tapping out part

* Paper read at the Paris meeting of the Institution of Mechanical Engineers, June 14, 1922.)

† For instance, on the Egyptian railways, by Mr. Trevithick (Engineering, 1911, vol. xci, pages 143 and 211); on the Atchison, Topeka and Santa Fé Railroad big Mallet locomotives (*Revue générale des Chemins de fer*, 1911, i, page 561).

* Similar remarks appeared in Engineering of August 13, 1920, page 215.

† One calorie is equal to 3·97 B.Th.U.

of the exhaust steam may be injurious to the draught, does not appear to be founded, as the heat of the steam taken from the blast pipe returns to the boiler, where it generates a practically equivalent quantity of steam, the balance, due to the expenditure of work and to external losses, being hardly one-fifth. With this very small difference, the quantity of steam available for the blast will remain the same.

Feed-water heaters are of the open type, steam being condensed in the water; or of the closed type, on the principle of the surface condenser. The open type is simpler, the condensed steam returns to the boiler, purified from solid matter in suspension, but possibly with a small quantity of oil. Precise information on the last point, after prolonged use, is of importance. The closed type rejects the condensed steam. Either it receives the cold water under pressure, or the water is heated under atmospheric pressure and delivered to the boiler by a hot-water pump. Another difference is due to the circulation of water in the tubes, or outside.

With the exception of the exhaust steam injector, a pump is a necessary adjunct to the heater. Pumps set in motion by the mechanism of the engine have been disregarded, and direct acting steam pumps, on the principle of the Westinghouse air compressor, are used. The steam consumption of these pumps, in proportion to the work done, is rather large; they exhaust into the heater, but the heat from that source, coming out of the boiler, reduces the recuperation due to the main exhaust. A few temperature measurements easily determine the proportion of heat from both sources. As an average, it may be assumed that, out of 80 calories, 20 come from live steam and 60 are recuperated. An advantage of the pump is that it makes easy the regulation of a continuous feed, at whatever rate wanted.

Amongst the old heaters, the Kirchweger has been largely used, warming water in the tender tank.* The same plan has been used for a long time on the London, Brighton and South Coast Railway. Couche also cites the pumps of Clarke, of Bouch, and the Ehrhardt heater. The Chiazzari pump† takes water from the tender and delivers it to a heater, receiving also exhaust steam, and then returns the hot water to the boiler. It is worked from the engine mechanism. The Mazza injector‡ takes water at a very high temperature, and works in connection with a Kirchweger heater. The Koerting double injector§ takes water warmed up to 75 deg. in a tubular heater.

The Lencauchez system‖ has, like the Chiazzari, a cold water pump, a heater condensing steam in the water, and a hot water pump delivering into the boiler. Exhaust steam passes first through an oil separator, working on the principle of changes of direction. The pumps are worked from the engine mechanism, but as at high speeds their action is inefficient, M. Lencauchez has proposed to reduce the speed by gearing.

The American heater of Copeland¶ is built on the same lines; the heater is inside the smoke box. The Strong heater** is intended to purify the water by heating; it consists of a high cylindrical reservoir full of water with two coils, one heated by exhaust and the other by live steam, with a filter on the top. The German heater of Rieger†† is a tubular one, with water in the pipes and steam outside.

The principal appliances in actual use are Davies and Metcalfe Injector, Weir Heater, Caille-Potonié Heater, Worthington Heater, and Knorr Heater. The exhaust-steam injector is largely used, principally in England.

The latest type of locomotive exhaust-steam injector is shown in Fig. 1, which represents the Davies and Metcalfe (Class F) injector. In its original form, exhaust steam alone being used, this apparatus delivered against pressures limited to 5 kg. per square centimeter (71 lb. per square inch), but has been improved to such an extent that, at the present time, pressures up to 10 kg. per square centimeter (143 lb. per square inch) can be dealt with; and the proportion of live steam necessary for higher pressures is, at the same time, largely reduced. Exhaust steam from the blast-pipe passes through an oil-separator, which consists of a perforated sheet-iron cylinder, covered with a sleeve of turkish towelling. The exhaust steam valve on the left in the figure may be closed by hand; then, in order from left to right, are seen the small supplementary live steam nozzle, the large exhaust steam nozzle, the water-nozzle, and a second exhaust-steam nozzle, which is connected with the draught tube. To keep the injector at work when the regulator is closed, it is only necessary to open the auxiliary steam-valve. To obviate this simple operation in cases where it has to be repeated at frequent intervals Messrs. Davies and Metcalfe have now designed an automatic steam-valve.

The general arrangement and the details of the Weir feed-pump and heater are shown on Figs. 2, 3 and 4. The pump has double-acting steam and water cylinders. In the heater the cast-iron shell, which forms the steam space, has branches for the admission of exhaust steam from the blast-pipe, and for water from the pump; there is also a connection for draining the condensation water. The copper tubes are expanded into headers, one of which is rigid with the shell, the other being free to move with the expansion of the tubes. The headers are divided in such a way as to divert the feed-water through the various passages of the heater, after which it is passed directly into the steam-space, through a special spraying valve situated at the top of the boiler.

In its latest form, the Caille-Potonié heater comprises: on the blast-pipe, a steam connection, with a hand-worked valve; and a regulator, proportioning the flow of steam. This consists of a piston, with the exhaust steam on one face, and a spring, with atmospheric pressure, on the other. The lowering of the temperature of water in the heater increases the rate of condensation and decreases the pressure; the resulting motion of the piston augments the area of the steam passage. A tubular heater, with three or four circuits of tubes, through which the steam passes in succession; this heater must be below the level of the bottom of the tender tank, so as to be constantly full of water. When it is not possible to place it low enough, a supplementary pump supplies it with cold water. A vent on the top of the heater allows the gases to escape. A hot-water pump, directly connected with a steam cylinder; exhaust steam from this cylinder is condensed in the heater. Caille-Potonié heaters to the number of 110 will soon be in service or in course of erection on the P.L.M. system. The Caille-Potonié heater is shown in general arrangement in Fig. 5. In this apparatus, the heater is placed below the lowest level of the water in the tender. A double-acting pump is specially arranged to deal with boiling water; vents, with small valves to permit the escape of steam, being provided. Fig. 6 represents the heater. This consists of a sheet-iron casing, which forms the water space, provided with a vent at the top; the tubes into which the steam is diverted, are expanded into headers, of which, one is fixed and the other movable.

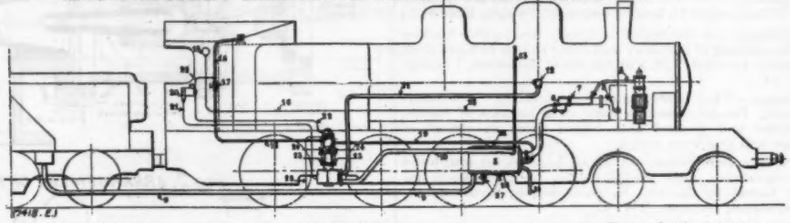
The Worthington heater* is a jet condenser. A double steam-pump, integral with the condenser, forces cold water into contact with the exhaust steam, and delivers hot water to the boiler. The hot-water pump is somewhat larger than that for the cold water, but not in proportion to the addition of condensed steam: consequently, water accumulates in the condenser, from which it automatically returns to the cold pump at intervals. Exhaust steam passes through an oil separator, and a vent allows air to leave the condenser. Five Worthington heaters in France are on trial by the P.L.M. Railway.

The Knorr heater became popular in Germany during the war. It consists essentially of a tubular condenser interposed between pump and boiler, with water in the tubes. A fair comparison of the different systems of heaters would require a knowledge of initial cost and expenses of upkeep, in regard to the economy of fuel. But there are, at present, difficulties in collecting exact figures on these points, as may be judged from the conclusions in the report of Mr. Lacoin to the International Railway Congress at Rome.*

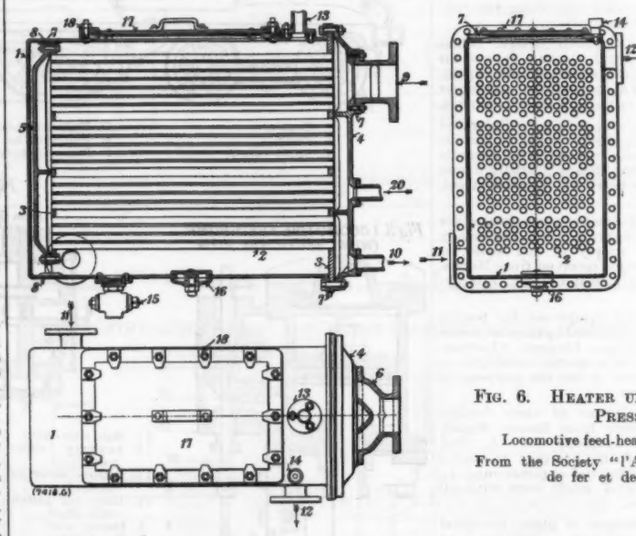
"Although certain railways have applied apparatus of that kind to a large extent, and it seems the time is coming for their general use, the trials do not permit, as yet, of sufficiently precise comparisons of the different systems being drawn. Early conclusions of these trials would be of great utility in assisting the rapid general adoption of feed-water heaters."

It may be added that available data, as a rule, show a decided economy of fuel due to the use of feed-water heaters; in some cases exceeding the average 10 per cent., which corresponds to the quantity of heat recuperated. This result may be due to some indirect advantages of the system.

Fig. 5. GENERAL ARRANGEMENT OF LOCOMOTIVE FEED-HEATER (CAILLE-POTONIÉ). MADE BY THE SOCIETY "L'AUXILIAIRE DES CHEMINS DE FER ET DE L'INDUSTRIE."



3. Tubular heater.
4. Exhaust pipe.
5. Steam intake.
6. Temperature regulator.
7. Exhaust-steam branch pipe.
8. Air-compressor exhaust.
9. Cold-water pipe.
10. Hot-water from heater to pump.
11. Discharge from pump.
12. Clack box.
13. Heater air-vent.
14. Heater drain.
15. Pyrometer.
16. Pyrometer pipe.
17. Pump steam-cock.
18. Pump steam-pipe.
19. Pump exhaust.
20. Mechanical lubricator.
21. Steam-pipe for lubricator.
22. Pump lubricating pipe.
23. Valves for escape of vapour.
24. Vents for vapours.
25. Vent-pipe.
26. Heater washing-out door.
27. Heater emptying cock.
28. Washing-out plug.



1. Heater box (sheet-iron).
2. Copper tubes.
3. Tube-plates (iron).
4. Forward cover (cast-iron).
5. Rear cover (cast-iron).
6. Steam inlet.
7. India-rubber joints.
8. Rear cover guides.
9. Steam inlet.
10. Condensed-steam drain.
11. Cold-water inlet.
12. Hot-water exit.
13. Air-vent.
14. Thermometer connection.
15. Drain-cock.
16. Washing-out plug.
17. Washing-out door.
18. Door fixing.
20. Pump steam-cyl. exhaust.

FIG. 6. HEATER UNDER ATMOSPHERIC PRESSURE.

Locomotive feed-heater (Caille-Potonié).

From the Society "l'Auxiliaire des Chemins de fer et de l'Industrie.

In conclusion, the question of feed-water heaters for locomotives may be summarised as follows:—

1. Feed-water heating with exhaust steam gives an economy of fuel or an increase of power, or both together. The results of practice correspond with the theoretical predictions on this point.

2. The use of steam pumps is convenient for fine regulation of a continuous feed, at least during prolonged runs without stops.

3. Tapping out part of the steam for heating is without a marked influence on the draught, as this allows a supplementary production of an equivalent quantity of steam.

4. Apparatus that return the condensed steam to the boiler reduce the consumption of water and allow a longer mileage after each wash out.

5. On the other hand, deleterious effects from oily matter in the boiler might be expected; however, no trouble from this cause appears to have been reported.

6. Appliances that eliminate the gases in solution in the water are to be recommended, as retarding the pitting and grooving of the plates. Measurements of the proportion of gases eliminated is desirable.

7. With each apparatus it is interesting to know what proportion of the heat received by the water is due to the exhaust of the engine apart from the exhaust of the pump.

8. Facilities for removing the scale from the heater are absolutely necessary.

* Couche, Voie, matériel roulant et exploitation technique des chemins de fer, vol. iii, page 280.

† *Revue générale des Chemins de fer*, June, 1879, page 445, and August, 1879, page 107.

‡ *Revue générale des Chemins de fer*, August, 1879, page 106.

§ *Revue générale des Chemins de fer*, May, 1880, page 319.

‖ Bulletin de la Société des Ingénieurs Civils, June, 1890, page 729, and June, 1898, page 110.

¶ *Revue de Mécanique*, 1899, i, page 649.

** Proceedings, I.Mech.E., 1881, page 539.

†† *Zeitschrift des Ver d. Ing.*, 1913, i, page 857,

* ENGINEERING, January 14, 1921, pages 42–3.

* Bulletin de l'Assoc. Intle. des Chemins de fer, April, 1922, page 539.